Utah Department of Transportation

CONNECTING COMMUNITIES

Manual for the Moving of Utah Bridges Using Self Propelled Modular Transporters (SPMTs)

May 30, 2008

This page left Blank

Introduction

This document is a compilation of research and referenced Specifications in U.S. Standard Units (Inch-Pound Units) for reference into the Department's design and construction contracts. Each section of this guidance document references other existing information found in Specifications, Codes and other Recommended Practices.

This document is written to the Designer or Engineer of Record (EOR); Contractor's Bridge Specialty Engineers working for the Bridge Contractor; Heavy Mover; Bridge Contractor; and the Construction Inspection unit. This document is organized into chapters and each chapter should not be considered stand alone. The only exception would be Appendix A of this document which is the tentative UDOT Supplemental Specification or a draft Special Provision for inclusion into the bid documents of UDOT bridge construction projects.

Applications and Exclusions:

This document provides design guidance for the majority of simply-supported beam and slab span types anticipated likely to be moved using Self Propelled Modular Transporter (SPMT) methods. In general, it applies to spans with modest skews (up to about 20 degrees) and for circumstances where the potential twist induced in the deck being carried as a consequence of unanticipated loss, unequal or uneven support is no more than about three inches at an extreme corner. In general, it also applies for higher skews, providing that the SPMT supports are arranged to be parallel to the end bents. Where this is not possible, and for any other special circumstances, the Designer should consider the appropriate location and orientation of the SPMT supports and should examine the likely induced twist, stresses and deflection changes using rigorous (e.g. 3-dimensional) structural analyses. This manual may be superseded by the owner on a case-by-case basis.

The information is to be utilized in an appropriate manner by Professionals licensed to practice engineering. The registered professional is responsible for the appropriate application of these recommended practices. Once released by UDOT it may be referenced in projects.

UDOT and FHWA Reference Manual

This document has been developed and adapted from the FHWA 2007: Manual on Use of Self-Propelled Modular Transporters to Move Bridges (FHWA SPMT Manual) and tailored primarily for use on UDOT projects, for circumstances and prevailing design and construction contract practices in this State. For situations not directly addressed herein, reference may be made to the FHWA Manual. In cases of inconsistency, precedence shall be given to the UDOT Manual. Information in this manual will be updated as deemed necessary by UDOT.

Acknowledgements:

Many thanks go to the participants of the UDOT Accelerated Bridge Construction Standards Workshop held in Salt Lake City, Utah on January 28 and 29, 2008. Following that workshop a task team of UDOT Engineers, Consultants, Heavy Movers, Bridge Contractors and Specialty Engineers assembled to finalize processes, procedures, and standards that are assembled in this document and will be utilized on future UDOT projects. This information was compiled under a contract to HDR/RN/Corven to accelerate the implementation of Accelerated Bridge Construction in Utah.

Table of Contents

Chapter General Description Page #

1.0	Preamble and Background	1
	1.1 General	1
	1.2 Acronyms	2
	1.3 Definitions and Terminology	3
	1.4 Description of Equipment	7
	1.5 References	10
	1.6 Equipment References	11
2.0	Roles, Responsibilities and Qualifications	13
	2.1 Description and General Needs	13
	2.1.1 FHWA	14
	2.1.2 Owner	15
	2.1.3 Engineer of Record (EOR)	16
	2.1.4 Prime Contractor	17
	2.1.5 Bridge Contractor	18
	2.1.6 Bridge Specialty Engineer for Bridge Contractor	19
	2.1.7 SPMT Firm	20
	2.1.8 SPMT Engineer	20
	2.1.9 Contractor's Geotechnical (Testing) Engineer	21
	2.1.10 Construction Engineering and Inspection (Representative)	21
	2.2 Submittals	23
	2.2.1 General	23
	2.2.2 Design-Bid-Build (DBB)	23
	2.2.3 Design-Build (D/B)	23
	2.2.4 CMGC	24
	2.3 Checklists	24
	2.4 Requests for Information (RFI) and Communication	24
3.0	Structural Considerations	26
	3.1 Instructions to the Designer	26
	3.1.1 Bridge Design Requirements	28
	3.1.2 Stress and Deflection Computations	33
	3.2 Standards and Go-By's	39
	3.3 Checklists for EOR	40
	3.4 References	40
	3.5 SPMT - Deflection Change and Required Jack Stroke	41
4.0	Instructions to the Contractors' Specialty Engineer	51
	4.1 Qualifications of the Specialty Engineer	51
	4.2 Criteria	51
	4.2.1 General Guidance and Load Factors for Span Construction on the Temporary Supports	52
	4.2.2 As-Designed Information	52

4.2.3 Guidance and Load Factors for Analysis of Span during Lifting and Movement of the Span 53
4.3 Bridge Structures Erection Stresses 53
4.4 Temporary Works Criteria 53
4.5 Checklists 54
4.6 References 54
5.0 Instructions to the Contractors' Heavy Lifter 57
5.1 Qualifications 57
5.2 Criteria 57
5.2.1 General Description 57
5.2.2 Temporary Works Criteria 58
5.3 Checklists 59
5.4 References 60
6.0 Bridge Contractor Considerations 62
6.1 General Information 62
6.2 Best Practices 63
6.3 Checklists at Bid Time 63
6.4 Checklists for Submittals 64
6.4.1 General 64
6.4.2 Traffic Control Plans (TCPs) 64
6.4.3 Bridge Staging Area (BSA) 64
6.4.4 Travel Path (TP) 64
6.4.5 Temporary Support Structure 65
6.4.6 Permanent Superstructure 65
6.4.7 Geometry Control (Deflection and Twist) Checklist 66
6.4.8 SPMT Movement System and Operations Checklist 67
6.4.9 Other Miscellaneous Information 68
6.5 Example Pre-operations Checklist for Jobsite SPMT Operations Manual 68
6.5.1 Initial Lift of Span at BSA using SPMT System 68
6.5.2 Transportation 69
6.5.3 Setting Bridge Span in Place 70
6.5.4 References 71
7.0 Bridge Inspection Unit Information 72
7.1 General 72
7.2 Camber Calculations and Field Measurement 72
7.3 Deflection and Twist 74
7.4 Span Deflection and Twist – Survey Monitoring Procedures 75
7.5 References 78
8.0 Appendix A- Deflection and Twist Monitoring 79
9.0 Appendix B- List of Heavy Lifters 87
10.0 Appendix C- Bridge Plan Sheets (Go-Bys)
8 sheets plus 1 completed example of Sheet 2

1.0 Preamble and Background

1.1 General

This document addresses the movement of completed superstructures with the particular focus on the use of Self Propelled Modular Transporters (SPMT) for the construction of bridges - either for the removal and replacement of an existing superstructure or for the lifting, movement and installation of a new, prefabricated superstructure, according to the particular project.

The original concept for the Manual for the Moving of Utah Bridges Using SPMTs came from the segmental design philosophy which has now been incorporated into the AASHTO Design Specifications and embraced by the industry. One feasible method of erection is shown in the bid documents and the successful contractor may tailor the actual scheme as long as performance standards are met. Also, the overall design concept is that by limiting the stresses in the concrete and the deflections of the structure a practical and undamaged bridge design may be moved without the need for more complex structural analysis than conventional beam theory on gross sections. It is understood that due to site specific issues, that these criteria may be perceived by some to be overly restrictive. In these cases, guidance is given on how to do a more refined analysis. Refining the analysis then gives a higher level of understanding and therefore a lower multiplier for the dead load of the bridge may be used for the twist analysis. These concepts were firmed up by hand calculations and then verified by finite element modeling of a representative bridge.

SPMTs are self-contained computer controlled platform vehicles that are able to lift, transport and place with precision, existing or newly prefabricated bridge systems weighing from one hundred to several thousand tons. The term “SPMT” is generic to the market and industry and is used in the singular and plural form throughout the remainder of this document.

Existing Standard Specifications apply to the pre-fabrication of the new superstructure (utilizing components, for example, such as steel or precast concrete girders and cast-in-place deck slab or box girder construction) at an off-site location. Only matters pertinent to the technique of using SPMT’s to facilitate work are addressed in this document.

The main benefit of SPMT construction is to facilitate the prefabrication of bridges off-site under carefully controlled conditions, subsequently followed by rapid deployment and installation on-site with minimal disruption and inconvenience to traffic and the community. It replaces the conventional construction sequential operations such as erecting beams, erecting forms, installing shear studs, tying reinforcement, placing and curing deck slab concrete, removing formwork and placing barriers and other appurtenances such as light poles, screens and signs. Typically, impacts on traffic may be reduced to a matter of minutes or hours compared to months required for more conventional on-site bridge construction.

Along with significantly reduced on-site construction time, other benefits may include improved work-zone safety, minimization of environmental impacts, improved constructability, improved quality and lower life-cycle costs, depending upon the project application and details The use of SPMT construction reduces the conventional sequence to one step - that of moving the prefabricated structure to its final position. However, it requires a commitment to time-saving through coordination, concurrent preparation, construction and prefabrication both on and off-site, all integrated with appropriate traffic planning and control operations.

1.2 Acronyms

AASHTO – American Association of State Highway and Transportation Officials
ASCE – American Society of Civil Engineers
ASME – American Society of Mechanical Engineers
ASTM – American Society for Testing and Material
AWS – American Welding Society
BM – Bench Mark
BSA – Bridge Staging Area
CEI – Construction Engineering and Inspection (Resident Engineer)
CMGC – Construction Manager / General Contractor
DBB – Design Bid Build
D/B – Design Build
EOR – Engineer of Record
EPA – Environmental Protection Agency
FHWA – Federal Highway Administration
FHWA SPMT Manual – FHWA 2007: Manual on Use of Self-Propelled Modular Transporters to Move Bridge
GLWP – Grade Line Wheel Path
HL – Heavy Lift Firm
HMWM – High Molecular Weight Methacrylate
LRFD – AASHTO Load Resistance and Factor Design Bridge Design Specifications
MSE – Mechanically Stabilized Earth
NCHRP – National Cooperative Highway Research Program
PBES – FHWA 2006: Decision-Making Framework for PREFABRICATED BRIDGE ELEMENTS and SYSTEMS, Publication No. FHWA-HIF-06-030
QC – Quality Control
QA – Quality Assurance
RFI – Request for information
R.R. – Rod Reading
SC&RA – Specialized Carriers and Rigging Association
SN – Skid Number
SPMT – Self Propelled Modular Transporter
TCP – Traffic Control Plan

TP - Travel Path
TRB – Transportation Research Board
UDOT – Utah Department of Transportation (Owner)
VOC – Volatile Organic Compound

1.3 Definitions and Terminology

The **AASHTO LRFD Bridge Construction Specifications, Second Edition, 2004 with Interim Revisions through 2007 (LRFD)** offers criteria governing temporary works in Section **"3.1 Temporary Works and 3.2 FALSEWORK AND FORMS."** In order to better address bridges the background to the Commentary C3.1.1 brings in other past reference documents.

UDOT adds the Section 3.2.1.1 Definitions to the AASHTO LRFD Bridge Construction Specifications, Second Edition, 2004 with Interim Revisions through 2007.

Allowable Stress - The stress that can be sustained with acceptable safety by a structural component under the particular condition of service and loading.[1]

Axle-line - Axle-lines are the rows of pairs of wheels that are positioned along a line across the narrowest plan dimension of the SPMT indivividual unit. (This is clarified further in Figure 3-1 of this document.) From the elevation view, it appears that the axles of one pair of wheels is aligned transversely and concentrically but not physically connected with another pair across the width (narrowest dimension) of an individual unit. These pairs of wheels can steer the unit and assemble in 360 degrees of direction.[3]

Brace - A member placed diagonally with respect to the vertical or horizontal members of falsework or scaffolding and fixed to them to provide stability.[1]

Bridge Contractor- The firm or Sub-Contractor engaged by the Prime Contractor to carry out the construction of the bridge(s), the Bridge Contractor may be the Prime Contractor. [3]

Bridge Movement - The generic term used to describe the transporting of an existing or prefabricated span by sliding, skidding, lifting, rolling or hauling techniques. [3]

Bridge Movement Traffic Control Enforcement - Police, Highway Patrol or other law agency or off-duty officers engaged by the Prime Contractor or his Sub-Contractor(s) for the enforcement of traffic control during construction, such as lifting, handling, transportation and erection operations. [3]

Bridge Movement Traffic Control Plan or Traffic Control Plan (TCP) - The overall operational plan for control of traffic during the installation or removal of a superstructure using SPMT construction.[3]

Bridge Movement Travel Path (TP) - The route taken by the SPMT System when transporting an existing or prefabricated bridge deck superstructure to or from the staging area. Individual TPs may be different for different spans, different bridge structures or different staging areas. [3]

Bridge Staging Area (BSA) - An area set aside for the prefabrication of a new bridge superstructure and/or for the demolition of an existing superstructure. The BSAmay be an area within the right of way, an area off-site set aside by the Owner or an area acquired by the Contractor or his Sub-Contractor(s) for the purpose of the project. [3]

Contractor or Prime Contractor - The firm or Contractor engaged by the Owner to carry out the overall construction and execution of the entire project. [3]

Contractor's Geotechnical Engineer - The Professional Geotechnical Engineer engaged by the Prime Contractor to perform a geotechnical assessment of the construction (BSA) and TP in order to determine allowable ground pressures or other constraints from the local geotechnical conditions. [3]

Factor of Safety - The ratio of predicted ultimate load to the calculated maximum service load.[1]

Falsework - Temporary construction used to support the permanent structure until it becomes self-supporting. Falsework would include steel or timber teams, girders, columns, piles and foundations, and any proprietary equipment including modular shoring frames, post shores, and horizontal shoring.[1, 2]

Formwork - A temporary structure or mold used to retain the plastic of fluid concrete in its designated shape until it hardens. Formwork must have enough strength to resist the fluid pressure exerted by plastic concrete and any additional fluid pressure effects generated by vibration.[1, 2]

Heavy Lift Engineer – The Heavy Lift Firm Engineer. A Heavy Lift Firm usually has its own Engineering Department available to develop detailed engineering calculations and Shop (Working) Drawings. [3]

Heavy Lift Firm (HL) - The firm or company who owns and operates the SPMT equipment and who typically is engaged by the Bridge Contractor to carry out lifting, transport and setting operations. [3]

HL Blocking - Material or prefabricated assemblies placed on top of SPMT platforms in order to support the load - e.g. blocking under the end of a beam. [3]

HL Shoring Towers - A purpose-made support device that maybe supported on a temporary foundation or placed on top of an SPMT platform to raise, lower or support a load - sometimes used in conjunction with blocking and/or additional hydraulic jacks, and / or cross frames. These may also be used with strand jacks for the taller lifts. Also maybe know as climbing jack systems for the 5 to 20 foot heights used in lifting bridge sections. [3]

Horizontal Shoring Beams - Adjustable or fixed length beams or trusses used as load-carrying members in falsework systems.[1]

Jack Range - The manufactures jack stroke dimensions. [3]

Load per Axle Line- The maximum load per axle line is generally taken per as 33 tons and 40 tons for 8 foot and 10 foot wide bogies. See the FHWA 2007 *Manual on Use of Self Propelled Modular Transporters to Remove and Replace Bridges*. The actual manufacture certified cut sheets will state the "Safe Operating Capacity" and will be part of the SPMT Submittal. This results in a maximum wheel load of 16.5 kips and 10 kips respectively. [3]

Load Test - The operation of load testing a frame, system or component in order to establish the rated capacity of the frame, system or component. LRFD Construction Specification Section 3.1.3 states "…in no case shall the rating exceed 80 percent of the maximum load sustained during load testing of the equipment." [3]

Operating Contingency - The engineering approach is not to fully utilize the total rated capacity of a component, system or sub-system, thereby allowing for an unplanned outage. (e.g. a flat tire, reserved stroke capacity in hydraulic cylinders) This redundant approach may add costs and some risk based evaluations are needed by the owner and contractor with the Heavy Lifter. [3]

Picking Height - For new span construction, it is the height of the span above the ground of the low member at theBSA. This is generally location which the bridge contractor transfers the custody of the span over to the Heavy Lifter. This is typically about 5 feet above the working surface. For span removals, this is the height above the grade which the Heavy Lifter takes custody. [3]

Post Shore - Individual vertical member used to support loads, including adjustable timber single-post shores, fabricated single-post shores, and timber single-post shores.[1]

Scaffolding - An elevated work platform used to support workmen, materials, and equipment, but not intended to support the structure being constructed.[1]

Self Propelled Modular Transporter (SPMT) Unit - The basic unit of an SPMT system is made up of a top load-carrying platform supported by several axle-lines with controlled but independently steered pairs of wheels each with a hydraulic jacking system enabling the whole platform to be raised or lowered under load and driven in any direction under computerized control conditions. SPMT units may be coupled together longitudinally or laterally to form a larger, integrated platform with the same attributes of lift, travel and maneuverability. [3]

Setting Height - For new span construction, the height above the grade of the travel path TP at which the span is to be placed onto its substructure. For span removal, it is the height of the temporary supports designed to receive the removed span. [3]

Shoring - A component of falsework such as horizontal, vertical, or inclined support members. For the purpose of this document this term is used interchangeably with falsework.[1, 2]

Specialty Engineer - A Professional Engineer registered in the State of Utah, other than the Engineer of Record (EOR) or his subcontracted consultant, who undertakes the design and drawing preparation of components, systems, or installation methods and equipment for specific temporary portions of the project work or for special items of the permanent work not fully detailed in the plans and required to be furnished by the Contractor.[3]

SPMT Allowable Ground Pressure - The maximum allowable pressure that the ground can sustain and can be safely counted upon for support of an SPMT unit without causing damage, undue overstress or deformation of the road-bed or pavement upon which the SPMT unit rests.[3]

SPMT Assembly - A group of individual SPMT units assembled and connected together laterally and/or longitudinally into a whole, integrated unit that operates under its own unified computerized control system. Operationally, this may for example, comprise all the SPMT units that support one end of the span; whereas another assembly of units supports the other end. [3]

SPMT Cross-Frames - Temporary lateral or longitudinal girders or bracing frames that connect separate SPMT units or assemblies of units, blocking and columns in order to impart greater stability. The cross frames also assist in holding the relative position of the units in the assembly.[3]

SPMT Firm – used here to describe a Heavy Lift Firm which uses SPMT technology. [3]

SPMT Ground Pressure - The pressure exerted on the ground by the SPMT unit while traveling or at rest - determined by dividing the total load applied by one SPMT unit by the neat plan-area of the platform of that unit without any spreading. [3]

SPMT Movement System - Refers to the use of multiple SPMT units and assemblies used for the lift, transport and setting of an entire span or spans of a superstructure. Physically, it refers to everything comprising the support system from the prepared ground surface to the underside of the supported load (e.g. bridge superstructure) including any load distribution devices placed underneath the wheels of the SPMT. Operationally, it refers to the general method of using SPMT's to construct a bridge. [3]

SPMT Platform - The top load carrying platform of a single SPMT unit supported by the wheels, jacking and suspension system and controlled by a digital control system for steering and leveling. [3]

SPMT Strong-Backs - Temporary lateral or longitudinal girders that are used to add stiffness to the platform of the SPMT unit or assemblies of units. SPMT Strong-Backs generally consist of a girder or a box beam located on the top deck of the SPMT Assembly. [3]

SPMT Super-Works - That part or entire assembly of blocking material, shipping containers, portable barges, grillages, cribbing, columns, towers, strong-backs, cross-frames, temporary lateral or longitudinal girders or frames, additional hydraulic jacks and all other ancillary equipment supported by the top platforms of individual or assemblies of SPMT units. Typically, this applies to everything between the top of the SPMT platform(s) and the underside of the supported loads (i.e. bridge superstructure).[3]

Temporary Retaining Structure - For the purpose of this document, temporary retaining structure refers to both earth-retaining structures and cofferdams.[1]

Tube and Coupler Shoring - An assembly used as a load-carrying structure, consisting of tubing or pipe that serves as posts, braces and ties, a base supporting the posts, and special couplers that serve to connect the uprights and join the various members.[1]

Ultimate Load - The maximum load that may be placed on a structure, causing failure by buckling of column members or failure of some other component.[1]

[1] captured verbatim from the AASHTO 1995 with 2008 interims: *Guide Design Specifications for Bridge Temporary Works*.

[2] captured from the AASHTO 1995 with 2008 interims: *Construction Handbook for Bridge Temporary Works*.

[3] applies to bridge construction and in particular to the use of Self-Propelled Modular Transporters for that purpose:

1.4 Description of Equipment

There are several types of SPMTs by various manufactures. In order to give an indication of their working rages, a notional size is given for the SPMT sizes and abilities. The responsibility is on the designer to insure that the final design is possible using generally available SPMT Systems.

A single SPMT unit has either six- or four-axle lines, with each axle line consisting of multiple wheels arranged in pairs and spaced up to a maximum of five feet. Units can be rigidly coupled longitudinally and laterally creating combined units that can have synchronized movement of all axles. The units are connected by electronic cable to a central computer, the controller. The driver operates the controller while walking with the units. If there is a computer malfunction, the SPMT's under each end of the span can be manually operated but the drivers must coordinate to ensure the movements are synchronized. Two drivers are also used when the ends of a span are set independently.

The controller has four basic commands: steer, lift, drive and brake. Computerized electronic steering allows movement in any direction: straight forward and backward, transversely, diagonally, at any angle, and carousel steering. Each pair of wheels can pivot 360 degrees about its support point. Loaded SPMTs shall travel at a walking pace of approximately 3 miles per hour (4.4 feet per second) and shall have a demonstrated maximum travel speed up to seven miles per hour (10 feet per second) depending upon load and terrain.

A four-axle SPMT unit is approximately 20 feet long without the power-pack unit; a six-axle unit is approximately 30 feet long without the power-pack unit. The power-pack unit adds another 9 to 20 feet to the length of each unit depending on the number of axle lines. SPMTs are transported to a bridge site on normal flatbed trailers or shipped in flat-rack containers. For highway transport, the six-axle units require overweight permits and units that are 10 feet wide require permits for both width and weight. The configuration of the SPMT assembly is the responsibility of the HL. These dimensions are only included as background. The Bridge designer should depict an appropriate number of units based on a 5 foot axle spacing and 8 foot wide individual unit. These 4 and 6 axle units schematically configured as shown on the Go-by's will indicate the concept to the contractor and his sub contractors.

Each SPMT unit comprises a top platform supported by multiple pairs of wheels arranged in axle lines of four wheels per axle line or eight wheels per axle line. Units with four wheels per axle line are 8 feet wide and units with eight wheels per axle line are 10 feet wide. Lift capacity and lift range vary by manufacturer, configuration (e.g. unit width) and ground conditions. Manufacturer websites are listed in the references of this section.

The top surface of the unloaded SPMT platform at its lowest position is at most four feet above the ground surface. Factors such as magnitude of load, tire compression, platform camber and ground surface variation along the Travel Path (TP) affect the loaded SPMT platform travel height. The preferred minimum platform travel height is 44 to 60 inches, but the platform may be as low as 36 to 50 inches during travel.

The minimum available vertical stroke of the SPMT platform is typically 24 inches and the vertical lift range (meaning the change in height of platform) is approximately 36 to

60 inches. For operational purposes, an available stroke of 16 to 20 inches should be assumed. The reserve stroke is good practice to account for small ground settlement.

An SPMT platform can be vertically adjusted up to 24 inches to keep the load horizontal without distortion while traversing uneven and sloping ground surfaces. SPMT's can travel on uneven terrain with surface variations up to 18 inches and on grades up to eight percent depending upon ground surface friction. Additional equipment for the vertical lifting can be mounted on the SPMT platform as needed; such as hydraulic jacks to extend the range of the lift height, blocking, strong backs and support frames, special connection frames, towers or shipping-container type supports and so forth, as necessary for the project. (The needs and use of such additional equipment is deemed to be the responsibility of the Contractor, the SPMT provider and their respective Specialty Engineer's - and is addressed elsewhere in this document.) The Owner or Design Engineer should indicate the terrain over which each unit will travel so that the SPMT Firm can anticipate the auxiliary shoring and jacking needs. On the platform itself, equal loads are maintained on each axle line through the SPMT's three-point or four-point hydraulic suspension system, which consists of two hydraulic rams per axle line with each ram connected to a hinged elbow supported by two wheels. If there is small ground settlement during a bridge move, the small height difference is compensated by the hydraulic system.

A set of SPMT units underneath one lift point can be connected transversely to a set of SPMT units under a second lift point through the installation of connecting cross-frames which may be required to minimize differential movement between the points. This same type inner connection between SPMT units could be appropriate for a large heavy deck that requires 4 points of support. The vertical datum monitoring of an expanded system becomes even more critical in these applications.

As can be seen in referenced FHWA 2007 each axle line has a maximum applied load capacity of 32 to 40 tons, depending upon unit width, and exerts a maximum ground pressure of 1500 to 2000 lbs per square foot depending upon the magnitude of the load. However, it is not always possible to make use of the maximum load per axle line because heavy loads being transported can create excessively high ground bearing pressures (refer to Contract Plans for anticipated maximum allowable bearing pressures). In such cases, additional SPMT units may be required to reduce the bearing pressure to an allowable level. Steel plates can also be placed along the TP to help spread the loads. Also, use of the maximum load per axle line may not be possible when loads have a high center of gravity. In such cases, additional SPMT units may be required if cross-frames connecting the units are not sufficient to ensure stability.

For the removal of a bridge span, SPMT units are first assembled and blocking is placed on top of their platforms. (Typically, blocking is used on top of the SPMT platforms to support each of the beams in a span.) The SPMT platforms and blocking are then driven under the span and the span is then lifted using the SPMT hydraulic systems. The loaded SPMT units then travel at normal walking pace to an off-site staging area. The span is then lowered incrementally by the SPMT units onto temporary blocking in readiness for demolition. A similar process, in the reverse order, is used to move a new bridge span into place. For further information refer to Section 1.2 of the FHWA 2007 reference.

There are two approaches to specifying the maximum allowable ground pressure anticipated at the staging areas and on the TPs:

a. The Designer determines the actual weight being moved and designates the maximum soil stress anticipated at the staging area and TP. The Designer should estimate the geometry and weight of the SPMT.
b. The Designer specifies the staging areas and TPs are to support 1500 pounds per square foot under the shadow area of the SPMT. The latter approach is selected for the Utah Design Bid Build (DBB) Contract Plans delivery. The *Contractor's Geotechnical Engineer* shall verify that the staging area and TP are suitable for all proposed construction operations including the SPMT movement. The Go-By #1 states that the Contractor shall stabilize the BSA and TP.

The overall stability and capacity of the SPTM system (including the *SPMT super-works*) are the responsibility of the *Heavy Lifter Engineer* and shall be clearly shown on the SPMT Shop Drawings.

Changes to or verification of stresses in the bridge superstructure itself necessitated by the use of the Contractors selected SPMT construction system shall be addressed by the Contractor's *Specialty Engineer*.

As with any technology, suppliers are revising their product on an ongoing basis. For this reason, supplier input is needed before the final BSA and temporary cast beds are configured. It is also advisable for the contractors to consult one or more heavy lift firms to gage the availability of equipment.

1.5 References

UDOT 2008: *Standard Specifications for Road and Bridge Construction*, Utah Department of Transportation, 2008

UDOT 2008: *Structures Design Manual,* Utah Department of Transportation, 2008

FHWA 2007: *Manual on Use of Self-Propelled Modular Transporters to Move Bridges*, Publication No. FHWA-HIF-07-022

FHWA 2006: *Decision-Making Framework for PREFABRICATED BRIDGE ELEMENTS and SYSTEMS (PBES)*, Publication No. FHWA-HIF-06-030.

AASHTO 2007: *AASHTO LRFD Bridge Design Specifications,* 4th Edition, LRFD, American Association of State Highway and Transportation Officials, Washington, DC.

AASHTO 2004: *AASHTO LRFD Bridge Construction Specifications*, 2nd Edition with Interims through 2007; American Association of State Highway and Transportation Officials, Washington, DC, Section 3, "Temporary Works" and related references herein.

FHWA/AASHTO 2004 International Technology Exchange Program Scan Trip on *Prefabricated Bridge Elements and Systems in Japan and Europe*, Report Number FHWA-PL-05-003, March 2005

AASHTO 1995 with 2008 Interims: *Guide Design Specifications for Bridge Temporary Works*, GSBTW-1, American Association of State Highway and Transportation Officials, Washington, DC, with particular reference to loads, factors of safety and stability

AASHTO 1995 with 2008 Interims: *Construction Handbook for Bridge Temporary Works*, CHBTW-1, American Association of State Highway and Transportation Officials, Washington, DC.

FDOT 2006: "Graves Avenue over SR 400 (I-4)" Florida Department of Transportation, February 2006

1.6 Equipment References

SPMT Equipment Manufacturer contact information and websites are shown below and on the next page.

Goldhofer Aktiengesellscaft
PO Box 1364
Germany 87683
011-49-8331-150
01-49-8331-15 70 201 fax
horst.haefele@goldhofer.de
www.goldhofer.de
Horst Haefele, Director of Sales Heavy Duty Modules
01-49-8331-15201 direct line

Nicolas Industrie SAS
BP3 - RN6
Champs-Sur-Yonne France
33 3 86 53 52 00
33 3 86 53 52 49 fax
contact@nicolas.fr
www.nicolas.fr
Jean Claude Amichault, Director

Scheuerle Fahrzeugfabrik GMBH
PO Box 20
Oehringerstrasse 16
Pfedelbach Germany D-74627
+49 7941 691-0
+49 7941 691-300 fax
info@scheuerle.com
www.scheuerle.com
Bernd Schwengsbier, Manager Sales, New and Used Vehicles

KAMAG Transporttechnik GmbH & Co., KG
Liststr. 3
89079 Ulm
+49 731 40 98 0
+49 731 40 98 109 fax
info@kamag.com
www.kamag.com

2.0 Roles, Responsibilities and Qualifications

2.1 Description and General Needs

The use of Self Propelled Modular Transporter (SPMT) construction reduces the conventional bridge construction sequence to one step - that of moving the prefabricated superstructure to its final position. However, it requires a commitment to time-saving through coordination, concurrent preparation, construction and prefabrication both on and off-site, all integrated with appropriate traffic planning and control operations. Also, the use of SPMT for bridge construction requires a clear handoff of information between the professional parties involved in the project.

Therefore, in order to adopt and successfully employ SPMT for construction, it is necessary to define the roles, responsibilities and qualification requirements of the various parties. The information flow, the types of submittals and reviews according to the types of contract should also be understood by all involved. To aid this effort checklists and Requests for Information (RFI) will aid in the communications. These are addressed below. Utah may clarify or modify these roles and responsibilities to meet contract types on a case-by-case basis.

It is the intent to follow contracting practices, policies and procedures for normal, conventional bridge construction as far as possible, and adopt or adapt as necessary for the use of SPMT for construction. The following are intended for clarification purposes and are not exhaustive or exclusive. Also, they are not intended to remove, relieve or assign contractual, legal or professional liabilities and responsibilities for the various work undertaken. The professionals involved are charged with clearly defining the basis of their design and assumptions so that all parties involved with the use of the SPMT equipment understand the limitations of the site, the limitations and requirements of the SPMT and the limitations of the structure being moved. This engineering effort concludes with a planning instrument followed by the jobsite execution.

Roles, responsibilities and flow of information are derived largely from the organization and contractual arrangements between the main parties, listed below, and illustrated in Figure 2.1

- Federal Highway Administration (FHWA)
- Owner (UDOT)
- Engineer of Record (EOR - aka Design Engineer or Designer)
- Prime Contractor
- Bridge Contractor
- Bridge Specialty Engineer for Bridge Contractor
- Heavy Lift Firm
- Heavy Lift Engineer
- Contractor’s Geotechnical Engineer
- Construction Engineering and Inspection (CEI aka Resident Engineer)

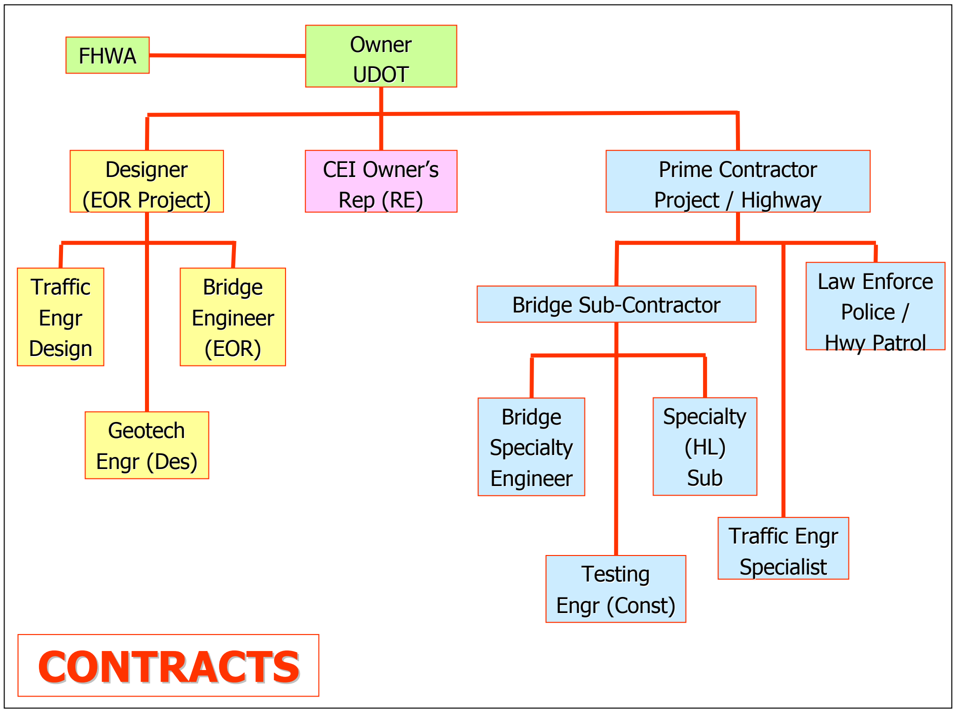


Figure 2.1 Contractual Organization

Roles, responsibilities and qualification requirements of the various individual parties are addressed as follows.

2.1.1 FHWA

The FHWA, on behalf of the US Department of Transportation, establishes overall policy for highway construction and serves as the primary funding resource for all Federal Aid Programs. FHWA establishes general processes and procedures to implement overall policy and authorizes projects. Projects are executed under recognized national standards and criteria - such as the AASHTO Bridge Design and Construction Specifications. In addition, through the auspices of the Transportation Research Board (TRB) and National Cooperative Highway Research Program (NCHRP), FHWA undertakes research and development in many areas in order to bring the benefits of new technology, ideas and concepts to the nations' vital infrastructure. Through the 50 State Departments of Transportation, the FHWA monitors implementation of policy and authorizes the execution of projects and new developments. Through its role as a major funding resource, FHWA monitors these efforts for compliance and accountability. UDOT has routine methods of communicating policy and engineering decisions with FHWA. Any deviations from AASHTO and/or UDOT Specifications must be approved by FHWA in advance.

For any project, the point of contact and communication for the FHWA is with the State Department of Transportation, in this case, Utah DOT. The general role and responsibilities of the FHWA is:

- Overall US DOT Policy
- Standards, Criteria
- Process, Procedures
- Funding Source
- Authorize Project
- Monitor Compliance
- Accountability

2.1.2 Owner

The Owner, in this case the Utah DOT, serves the people of the State of Utah by identifying the needs for new roads and bridges, maintaining existing inventories and acting as the second funding resource for major improvements.

In the role of Owner, UDOT identifies and defines a new project, sets standards and criteria, determines the available funding and overall schedule, executes or has the design executed on its behalf, prepares contract documents, advertises and takes bids, executes construction contracts, issues notices to proceed, approves sub-contractors, performs or engages firms to carry out CEI in order to monitor compliance with the contract, conducts independent Quality Assurance (QA), liaises with the FHWA, authorizes and makes partial and final payments for work completed.

In this role, the Owner must first determine that a bridge project, whether new or a replacement, is suitable for SPMT methods - in the sense of being both financially beneficial and technically feasible, including from the perspective of geotechnical conditions along the Travel Path (TP) and the Bridge Staging Area (BSA). When proven viable, the Owner has then to implement the process, for which it is necessary to establish the following:

- The necessary Design Criteria and Standards to be used
- Have the Bridge Design developed for appropriate SPMT methods
- Incorporate SPMT methods in Contract Documents (Plans / Specs)
- Identify or provide Staging Area and TP
- Determine and set the overall Schedule or Time Constraints
- Establish acceptable Traffic Operations, Diversions, Routes and Controls
- Advise and arrange coordination with Traffic Control Law Enforcement

The necessary technical design activity, plan preparation, preparation of specifications and other contract documents and the production of a set of Plans for Bid, are usually undertaken by a Professional Engineer who may be an employee of the Department or a firm engaged by the Department to carry out these Professional services. The Owner establishes or defines the qualification requirements for the services to be performed by this professional firm or person known as the EOR. Throughout the bridge development and construction process the Department will be asked to review and approve materials, methods and criteria. Approval of a particular request does not imply an overall acceptance of liability or responsibility for ancillary calculations, materials, or methods.

2.1.3 Engineer of Record (EOR)

The EOR is often referred to as the Designer or Design Engineer. Engineers of Record are Engineering Professionals engaged by the Owner to carry out the design of projects. For a project, the EOR is responsible for coordinating the activity of various engineering disciplines - such as highway, bridge, traffic, geotechnical, electrical or mechanical as necessary for the particular needs of the project. The EOR maintains close contact with the Owner usually (and preferably) throughout the entire project from the preliminary design phase through to final completion of construction. The EOR represents the interests of the Owner and provide advice throughout the process. Particular duties include such as:

- Close contact and liaison with the Owner
- Execute the Design
- Coordinate Engineering Disciplines
- Establish required Standards and Quality for Project
- Prepare Project Plans and Specifications
- Establish Pay Items and Quantities
- Review and Approve of Contractor’s Proposals (Shop Drawings)
- Advise Owner on matters of technical compliance and QA/QC

In addition the following specialist tasks are to be preformed by the Bridge Design, Traffic Engineering and Geotechnical Engineering.

- Bridge Design
  - Structural Bridge Design
  - Locate Utilities in the BSA and Travel Path (TP)
  - Review of Shop Drawings and Proposals
  - Review, approve use of SPMT
- Traffic Engineering
  - Traffic Plan
  - Approvals
  - Police Liaison
- Geotechnical Engineering
  - Bridge Foundations (temporary and final) including settlement
  - Construction Area including settlement
  - Approvals

In these roles within the organizational and contractual structure, each discipline is directly or indirectly in the service of the Owner and is the EOR responsible for work under that discipline.

The EOR shall be a Professional Engineer, registered or licensed in the State of Utah to perform engineering services in the discipline required for the project or portion thereof. The EOR maybe contracted through a Design Build (D/B) contract and serves in the same role as described above.

2.1.4 Prime Contractor

The Prime Contractor is the firm - usually selected on the basis of being an approved bidder and offering the lowest bid price for a project in the Design Bid Build (DBB) procurement - that is then engaged by and enters into a Contract with the Owner to construct the project in accordance with the bid Plans and Specifications. A Prime Contractor often engages the services of various sub-contractors to carry out particular parts of a project - in this case, perhaps the construction of a bridge or the use of SPMT service provider. Via the Contract Documents (Plans and Specifications prepared by the EOR) the Owner may establish or define technical, financial or qualifications he expects to have satisfied in order that project be executed properly.

Regardless of actual sub-contract arrangements or qualification requirements, from the perspective of the Owner, for all contractual purposes and contract administration, no distinction is made between the Contractor and his Sub-Contractors (including any Bridge Contractor, Heavy Lift or SPMT Firm and their own professional engineering support firms) - i.e. all communication and contract administration is solely between the Owner and the Prime Contractor.

The responsibilities of the Prime Contractor include, but are not necessarily limited to;

- Overall project control
- Contract compliance
- Researching and disseminating information on local ordinances and utilities as they relate to the construction / casting site.
- Coordination (of all sub-contractors, SPMT Firm, traffic, law enforcement, etc)
- Sub-Contractor Performance
- Quality Control (QC, technical needs, compliance)
- Contractual Agreements
- Construction Schedule (Program)
- Expediting all of the project in accordance with the plans and specifications
- Maintaining progress of work
- Keeping all records and reports as required by the Contract
- Preparing and submitting invoices and making payments etc.

In certain circumstances, such as the construction of a very large bridge where the bridge itself - or several bridges in a corridor or interchange - constitute the major cost of the project, usually the Prime Contractor would be a Contractor who specializes in bridge construction. On a major highway project it is frequently necessary for the Prime-Contractor to assign the construction of bridge and similar structures to a Bridge

Contractor because of the special nature of the work and/or the construction disciplines involved.

For our present purpose, this is assumed to be the case. However, what follows should apply equally to either a Prime Contractor acting as a Bridge Contractor or to a Bridge Contractor. For consistency in this document the term Contractor is directed to the Bridge Contractor. It is irrespective of the prime or sub-contractor role in this document.

2.1.5 Bridge Contractor

With specific focus to the construction of the bridge itself, the main role and responsibilities of the Bridge Contractor are summarized below:

- Structure Construction
- Knowledge, special skills
- Coordinate with Roadway Contractor
- Coordinate Specialties
- Technical expertise
- Execute work
- Schedule and Progress
- Keep Records
- QC for Structure
- Invoices and Payments

The roles and responsibilities of the main firms that provide special engineering services, SPMT equipment or testing services to the Bridge Contractor are defined below. Occasionally, these services may be engaged directly by the Prime Contractor, depending upon the needs of an individual project or organization. Communication and the work flow of engineering data should follow the processes outlined in this document. (More information on such special services is provided below.)

Usually, a Bridge Contractor will be deemed to be technically qualified for the construction of a type of bridge structure. The Bridge Contractor shall demonstrate experience in the construction techniques required to satisfy the Project Specifications and can demonstrate to the satisfaction of the Owner a successful history and direct engineering responsibility for the construction of bridges ***by conventional means*** on previous similar projects (as currently required by UDOT) - and by supporting such history by references from previous Clients.

The advanced construction techniques involving a SPMT Firm is based on the Bridge Contractors submittal of a specialty firm satisfying the requirements of the Project Specifications. The SPMT Firm and SPMT engineer required qualifications are defined in the Sections 2.1.7 and 2.1.8 below.

2.1.6 Bridge Specialty Engineer for Bridge Contractor

The Contractor's Specialty Engineer is a Professional Engineer (registered in the State of Utah, other than the EOR or his subcontracted consultant) who undertakes the design and drawing preparation of components, systems, or installation methods and equipment for specific temporary portions of the project work or for special items of the permanent work not fully detailed in the plans and required to be furnished by the Contractor. Such items include but are not limited to; pot bearing designs, non-standard expansion joints and Mechanically Stabilized Earth (MSE) wall designs. The Specialty Engineer may also provide designs and details for items of permanent work, determined by the Owner, to be "minor" or "non-structural". The Specialty Engineer may also provide the design of Temporary Works, such as falsework and formwork, erection trusses or gantries, casting machines, form travelers, Heavy Lift Equipment, SPMTs, and the like.

The Specialty Engineer may be an employee or officer of the Contractor, or a Fabricator, an employee or officer of an entity providing components to a Fabricator or Contractor, or an independent consultant.

With regard to the use of SPMT equipment, the Contractor's Specialty Engineer is responsible for any dimensional, structural or similar physical changes to the superstructure itself and for the verification of stress levels, for the assessment of the potential for cracking and for the verification the strength capacity of the superstructure as a consequence of the use of the Contractors elected SPMT construction method. (This applies to the permanent superstructure itself, not the SPMT system, its components or related geotechnical considerations.)

The above includes, but is not necessarily limited to effects arising from: changes of locations of temporary and/or permanent support conditions, changes to cross-section component sizes and/or connectivity (shear studs or shear reinforcement), relocation of construction joints (in any plane), sequence and installation of pre-stressing forces (by pre- or post-tensioning).

It also includes geometric controls to limit distortion (twist) or significant differences in deflection or camber from unintentional support settlement or differences in anticipated elevations, unexpected changes of conditions during lifting, transportation and setting of the superstructure.

In the event of cracking or damage, the Contractor's Specialty Engineer is to be responsible for inspection of the superstructure, the development of repair proposals and verification of the repaired superstructure - all supported by calculations and UDOT Specifications and manuals, as necessary. The Specialty Engineer shall submit a report of the repairs and supporting calculations to the Owner and EOR.

A Specialty Engineer is deemed to be qualified if he has (a) Registration as a Professional Engineer in the State of Utah and (b) the education and experience necessary to perform the submitted design as determined by the Utah Division of Occupational and Professional Licensing.

2.1.7 SPMT Firm

The SPMT Firm is responsible for the provision, application and operation of Heavy Lift or SPMT equipment either for the removal and replacement of an existing superstructure or for the lifting, movement and installation of a new, pre-fabricated superstructure. Included in the construction specification for the movement is a requirement for the contractor to monitor deflections or stresses as per the contract plans in the presence of the engineer. SPMTs are special self-contained computer controlled platform vehicles that are able to lift, transport and place with precision, existing or newly prefabricated bridge systems weighing from one hundred to several thousand tons.

For this purpose, the SPMT Firm is shown as being under contract to the Bridge Contractor rather than being engaged directly by the Prime. It is possible that the SPMT Firm is engaged directly by the Prime Contractor but this is not a preferred practice because the Bridge Contractor's control is clouded. Even so, all qualifications and requirements for compliance with the contract documents would remain wholly unchanged. (This subtle possibility illustrates the need for the main contract and all communications and contract administration to be solely and completely between the Owner and the Prime-Contractor and not between the Owner and any other sub-contracted parties or firms, including the Contractor's Bridge Specialty Engineer.)

A SPMT Firm, is deemed to be qualified if it can demonstrate to the satisfaction of the Owner, a successful history and direct engineering responsibility for the application, use and operation of the SPMT equipment on previous similar projects. The SPMT Firm will support such history by references from previous clients.

2.1.8 SPMT Engineer

The SPMT Engineer is responsible for the overall stability and capacity of the SPTM Movement System itself (including all *SPMT super-works*) along with all operational constraints of the SPMT Movement System that are to be clearly shown on Working Drawings (Shop Drawings), operational manuals, instructions and procedures.

Note that the SPMT Movement System also includes the SPMT Super-works whether designed by the SPMT Engineer or by another party (such as the Bridge Specialty Engineer). To clarify, as far as the Owner and EOR view the use of the SPMT equipment means and methods, the SPMT Engineer is responsible for everything from the point of contact of the wheels with the ground surface, to the underside of the supported superstructure, along with requirements arising from the need to meet clearances to existing features or obstacles within the BSA and along the TP to the installation at the bridge site - and vice-versa for removal and demolition of superstructures. The temporary support elevations and the setting height are geometric issues that will involve as-cast survey information that should be closely coordinated by the Bridge Specialty Engineer and Contractor.

For SPMT construction, the SPMT Engineer typically is not the Bridge Specialty Engineer. The SPMT Engineer is generally a Mechanical Engineer and/or a specialized

Structural Engineer perhaps with little knowledge of the bridge component itself and the background of the 75+ year serviceability requirements articulated in the AASHTO LRFD Bridge Code and UDOT Bridge Manual.

The SPMT Engineer is deemed to be qualified if he can demonstrate to the satisfaction of the Engineer, a successful history of direct engineering responsibility of the application, use and operation of SPMT equipment on previous similar projects. The SPMT Engineer shall support such history by references from previous clients.

2.1.9 Contractors' Geotechnical (Testing) Engineer:

With regard to the use of SPMT equipment, the *Contractor's Geotechnical Engineer* is responsible for field verifying that the EOR conceptual Bridge Staging Area (BSA) and TP are suitable for all proposed SPMT construction and effects arising from the Contractors selected SPMT construction method and operations. This includes calculations and checks of allowable ground bearing pressures, soil preparation and improvements to the BSA and TP along with any precautions necessary and / or means by which SPMT construction operations may be facilitated - e.g. such as the use of metal plates or spreader beams to disperse loads over buried utilities or soft soils. Pavements and surface conditions are critical in areas where the SPMT are making sharp turns and the SPMT Firm shall be consulted concerning the use of steel plating or mats.

The Contractor's Geotechnical Engineer is deemed to be qualified if he has the following qualifications – (a) Registration as a Professional Engineer in the State of Utah and (b) the education and experience necessary to perform the submitted design as determined by the Utah Department of Business and Professional Regulation. The Geotechnical Engineer may be an employee or officer of a local Geotechnical testing firm qualified to test embankment and stabilized surfaces for UDOT projects.

2.1.10 Construction Engineering and Inspection (Representative)

The CEI team is sometimes referred to as the Resident Engineer or Site Representative. The main role is to represent the interests of the Owner at the project site in order to ensure compliance with the requirements of the construction contract. The overall duties and responsibilities of the CEI are summarized below:

- Represent Owner
- Ensure Contract compliance
- Establish and perform QA to check Contractor's QC
- Make on-site checks to ensure Contractor complies with technical requirements
- Measure work done
- Monitor compliance with any incentives and disincentives
- Provide Owner with regular Progress Reports
- Approve Progress Payments
- Resolve issues, responses to submittals and expedite RFI's.
- Issue and monitor Change-Orders or variations

- Make diaries and keep records
- Verify measured deflections or stresses were within contract limits during moving process.

In UDOT practice, the CEI is seen as a vital element of communication between the various parties to the construction project in addition to the other duties and responsibilities listed above. Although the Prime Contractor is ultimately responsible for coordinating all construction and related activities, the CEI may often be crucial to the success of the project for both the Owner and the Prime Contractor - for instance by anticipating forthcoming needs, activities, events and making sure that various parties not legally bound under the terms of the contract (e.g. outside authorities, other firms) communicate and/or are informed as necessary. Consequently, a CEI plays an important, active role - not simply one of passive monitoring and payment authorization. This active aspect of the CEI role should be encouraged - possibly via the manner in which his agreement with the Owner is set up to function. This independence was also noted at the UTAH ABC Workshop by the group present requesting the distortion and twist monitoring be provided by the CEI inspection unit. The Heavy Lifters all preferred this method.

Thus said, the CEI role in project delivery begins with communications and facilitation. It is essential that the CEI be advised of, and when necessary directly copied, on submittals and the due dates for responses. The CEI tracks responses and follow up with telephone calls and messages to facilitate responses. The CEI should do likewise with RFI by the Contractor from his side of the project organization. This requires identification of various submittal requirements (e.g. Shop Drawings, Manuals and RFI and their Responses), their respective technical and contractual content and the process by which they are most effectively handled to expedite progress. This is addressed in the following section (below).

The necessary qualifications for a CEI Firm, Person or Organization are usually established by the Owner. Generally, for a major project, a Professional Engineer registered or licensed in the State of Utah, with several years experience in the necessary and appropriate areas of construction activity is required to lead the CEI teams' site operations. Depending upon the size of the project, he may be assisted by other professional engineers or site engineers and site inspectors with expertise in the various disciplines and types of work. For SPMT projects, direct experience with the oversight of a similar previous project would be an advantage - however, it must be acknowledged that this is new and developing activity so persons with direct experience may not be readily available. On a case-by-case basis, the Owner should qualify the requirements for the CEI specifically for bridges involving SPMT movements - possibly by requiring a number of years' experience, or involvement by key staff or part-time specialized sub consultant in closely related work from similar previous projects or in other Heavy Lift Firm (HL) industries - e.g. Petrochemical, Marine, Ship-Building, Military or Nuclear industries and/or complex bridge construction industries like the segmental bridge construction industry.

2.2 Submittals

The primary purpose of submittals is to communicate information from one party to another so that the necessary technical, engineering and contractual tasks are handed off and can be expedited properly with due regard for the roles, responsibilities and professional disciplines involved. It is for this reason that much of the foregoing "roles and responsibilities" were elaborated. The previous section has captured the "who's" what remains to be defined are "the lines" of important and clear communication. Many of the "hows" and ingredients of these submittals are included in subsequent sections of this manual. The Owner (UDOT) communicates with the CEI, the Designer and the Prime Contractor. The Designer communicates with the owner and their sub consultants (Traffic Engineer, Geotechnical Engineer and Bridge Engineer). All communication should be copied to the CEI. Like the Designer, the Prime Contactor would communicate with the owner and the Bridge Sub-contractor, the Traffic Engineering Specialist and Law Enforcement. Again, all correspondence should be copied to the CEI. The Bridge Sub-contractor will also have sub-contractors with witch they will communicate. These include the Bridge Speciality Engineer, the Testing Engineer and the Heavy Lifting Firm.

2.2.1 General

The processing of submittals changes slightly with the contracting delivery tool. This section attempts to clarify roles and responsibilities by delivery methodology.

2.2.2 Design-Bid-Build (DBB)

The DBB process has the EOR working for the Owner. He must represent the Owner without any perceived real or potential conflict. This has been the standard modus-operandi for most, if not all, small and large scale civil engineering work in the public sector for many decades. The DBB method comes with attendant roles, responsibilities and activities of the various parties and thus has an implied consequence of appropriate checks and balances. The DBB process was also based soundly upon engineering experience with an assured level of professional responsibility and conduct taking into account construction contract histories and precedents from legal cases. The roles and responsibilities outlined in this document are based on such traditional DBB contracting methods.

2.2.3 Design-Build (D/B)

In the public sector, the Design-Build process evolved out of a desire to have a single point of responsibility. In effect, for many D/B projects, the Bridge Specialty Engineer and the EOR are one and the same party. For D/B, this has removed the EOR from the role of directly advising, working for and protecting the interests of the Owner. In effect, the Owner has no direct contracted Engineer responsible for the Design, and independent checking and review of submittals throughout construction. Some of the latter has to be assigned to, or be assumed by, the CEI on D/B projects. However, in practice, this may not always be possible because of the needs of different professional engineering and technical disciplines. Caution is required because the delineation of responsibilities within the D/B entity is not the responsibility of the DOT - whereas in practice, a clear delineation of responsibilities is necessary. It is recommended practice that the D/B team clearly delineate the EOR, Bridge Specialty Engineer, and the SPMT Engineer to match the roles and responsibilities outlined in this manual. It would clarify roles and the necessary checks and balances within the D/B team.

Other D/B procedures may allow the EOR to perform the Bridge Specialty Engineer's work but they may not be totally aware of OSHA and Rigging standards discussed in other sections of this manual. It was the general spoken opinion of the UTAH ABC workshop held in January 2008 that the SPMT Firm and the SPMT Engineer be separate from the EOR and Specialty Engineer. These roles and scopes are up to the D/B entity which is generally headed by the Contractor and proper internal communication is essential to avert any omissions.

2.2.4 Construction Management / General Contractor (CMGC)

While still in the early plan development phase of a CMGC project delivery the Contractor working with the EOR will have an agreed bridge span erection concept. At that point the EOR will complete the plans based on the support points agreed in the concept and the process in the following manner:

- The EOR working for the DOT will review construction and in-service stresses (and displacements) while finalizing the plans.
- The EOR will review and insert the supplemental UDOT Bridge Movement Specifications addressing the use of SPMT's and the need to have a qualified Bridge Specialty Engineer and Heavy Lift Firm along with standards and completed "Go-by" sheets.
- The Contractor and his SPMT Firm may propose to his Bridge Specialty Engineer adjustments to the scheme in the plans.
- When the construction contract is awarded, the contractor will retain a Bridge Specialty Engineer to analyze the bridge for erection stresses and submit shops and erection computations to the EOR.
- The Bridge Specialty Engineer will review the SPMT submittal for completeness and compatibility to the assumption incorporated in the Bridge structural analysis.
- The Bridge Specialty Engineer will reference any transferred engineering data into his plans and complete the package for review by the Contractor.
- The contractor will then submit the package to the DOT.

2.3 Checklists

Check lists are tools to reasonably assure a party has considered items deemed generally acceptable to the practice. There are checklists within this manual for consideration by the EOR, Bridge Specialty Engineer, Heavy Lifter, Contractor and CEI units.

2.4 Requests for Information (RFI) and Communication

Communication protocols are normally established for the project by the project team. The RFI process is intended to accelerate the communication of interpretations of intent. It is not used to change a Contracted Specification or modify the intended application. A

Change Order is necessary to modify the Contract or information with in the contract documents (e.g. Plans and Specifications). Likewise all parties must understand that the use of an RFI to communicate engineering data is not wise and is not recommended. Signed and Sealed reports, calculations and plans are the methods required by the Utah Professional Engineers and Professional Land Surveyors Board.

3.0 Detailing Consideration and Design Requirements

The window of traffic interruption by the Self Propelled Modular Transporters (SPMTs) placement of a superstructure may require the Designer to consider construction details that will enhance the Bridge Contractors operations. These selections may shorten or lengthen the interruption and must be investigated for the added value by the Owner and Designer on a case by case basis.

3.1 Instructions to the Designer for Detailing Options

These considerations are mentioned in no particular order:

a. Construct the Traffic Railing after span placement thus avoiding the issue of post handling of the cracked barrier or consider installing temporary external post-tensioning of the deck and barrier.
b. Casting of the span by under running the length by 2.5 inches (ie 1.25" gap each end) to facilitate span placement in a structure involving a single span and have the plans denote the anticipated placement of the superstructure in relation to tolerances and dimensions of the substructure. Plans should also note the following "Dimensional Tolerances addressed in Construction Specifications shall be enforced stringently against overages." This is not always necessary when substructure detailing is sequenced to facilitate span placement.
c. The bearing pads may be attached to the bottom of the girders. However, this attachment shall not impede the future removal and replacement of bearing pads. See.Go-By sheet #5 for attached bearing concept.
d. When analyzing spans being removed and demolished the Designer may waive all serviceability (Service I and Deflection) as required by this UDOT manual. The designer should check the span for Dead Load and construction loading in accordance with Strength Limit States as defined in LRFD 3.4.2.1.
e. Include approved crack sealant and injection techniques as denoted on the Go-By sheet #5.
f. How much earthwork/site preparation is required to accommodate the Travel Path (TP) of the SPMT unit? Can the temporary supports be moved in and how much temporary deck restraint is needed? This is an iterative process that will approach a point of greatly diminished return. See Section 3.1.2 of this manual for stress and deflection computations.
g. Generally the designer should estimate the number of "Axle Lines" based on 25 tons per axle line. This will give adequate capacity for the weight of the SPMT super-works defined in Section 1 of this manual. This approach (25 tons per axle) also includes the 10% contingency for out-of-service axles discussed in Reference FHWA 2007. Refer to Figure 3-1 for clarification of what is meant by the term "axle-line" within a single 6 axle or 4 axle unit. The manufactures have an operating capacity of 33 tons per axle line. Multiple units maybe connected into an assembly. As there are many permutations of equipment available the measurements here are for a notional vehicle. The Designer can then look at the TP geometry and determine if existing structures to be crossed have an adequate capacity. To determine adequate capacity, refer to UDOT's permitting criteria.

Temporary Shoring, permanent strengthening and /or repairs may be stipulated in the UDOT construction plans. With this size load, longer SPMT assemblies may be required if crossing any existing structures that do not have the capacity to support 33 tons per axle line.

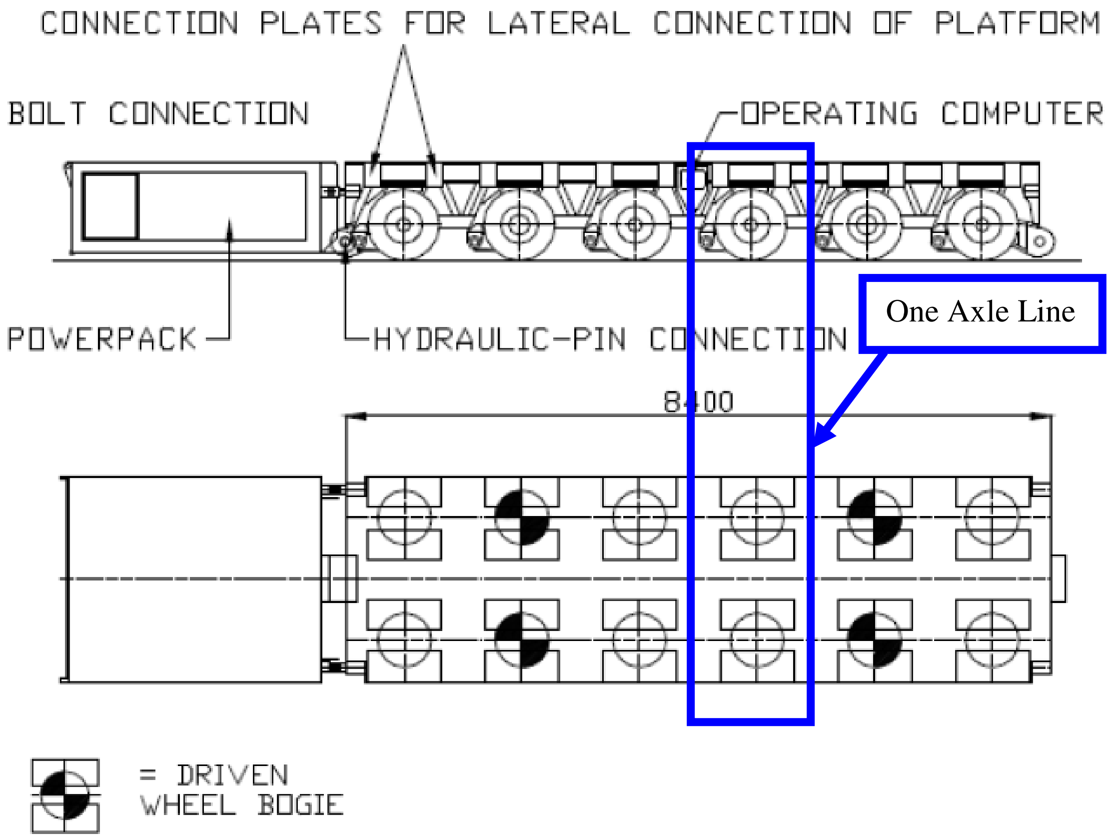


Figure 3-1:Illustration of typical SPMT and Axle Line

h. The Go-By sheet #1 indicates the general types of sheets used to convey the sequence of construction for "Flanking Movements" of span relocations. A drop down concept is also shown (see Go-By sheet #7). The Designer should make an estimate of the weight of the truss and supports of the system for the length of the span and the lead and the rear SPMT assemblies. Borrowing from the bridge gantry community, for example, a 140' long span weight 1200 tons could be carried by a 220' long truss weighing approximately 220 kips (110 tons) or 1 kip per foot for the truss weight. At 25 tons per axle line, a minimum of 58 axle lines are required. The Contract Plans would include schematic construction sequencing sheets with 32 axles in each of the lead and rear assembles of the SPMT units (to respect the typical SPMT configurations in increments of 6 and 4 axle units). These could be oriented 4 across and 8 axle lines long - making each assembly 40 feet of SPMT's plus a 20 feet of power pack. This general guide should enable a concept to be conveyed on the Plans. The Bridge Contractor, his Heavy Lift Firm and Specialty Engineer will make the submittal of the selected system. As there are many permutations of equipment available the measurements here are for a notional vehicle. This example also gives a gross weight based on an upper limit of 33 tons per axle line for the whole assembly of less than 2,112 tons. The Designer can then look at the TP geometry and determine if existing structures to be crossed have an adequate capacity. To determine adequate capacity, refer to UDOT's permiting criteria. Temporary Shoring, permanent strengthening and / or repairs may be stipulated in the UDOT construction plans. With this size load, longer SPMT assemblies may be required if crossing any existing structures that do not have the capacity to support 33 tons per axle line.

i. Choose a level of analysis that is most economical for the project purpose. For this section, the concept of "basic beam analysis" refers to an engineering design analysis which takes into account staged construction of the superstructure span. Use transformed section properties for different classes of concrete in a deck slab and prestressed concrete beam. Do not use transformed section properties that consider the deck slab reinforcement in beam analysis. Nor does such basic beam analysis take into account the three-dimensional effect of the deck inadvertently twisting during movement.

3.1.1 Bridge Design Requirements

The span shall meet all AASHTO LRFD and local code requirements for the "in-service" condition. All LRFD Strength Limit State requirements must be met in any temporary condition. These additional requirements are invoked to guard against damage to the superstructure during handling and placement of completed spans with SPMT's and other heavy lift techniques. Other sections of the LRFD Code guard against permanent distortions. This section highlights many of those sections of the LRFD Design code with additional specific UDOT requirements. The following requirements are presented as additions or deletions to the 2007 AASHTO LRFD Bridge Design Code. They are presented in numerical order.

a. **LRFD Section 3.4.2 Load Factors For Construction Loads** This AASHTO LRFD section is broken into two subsections. Section 1 addresses the Strength Limit State and Section 2 addresses the Service Limit State. The following additional requirements are extended to apply to launched and relocated spans using SPMTs.
   1. The Designer shall analyze spans on the assumed SPMTs supports based on the Strength I Limit State with a load factor equal to 1.25. For bridge sections to be removed asphalt overlay thicknesses and density should be validated by field measurement.
   2. The Designer shall also check the spans to be brought into service for displacements based on Service I Limit State. Service stresses in the span while being supported on the SPMTs shall have a service load factor on dead load of 1.15 (handeling impact factor) as a vibration and twist allowance providing that all SPMT movement is undertaken under slow, walking pace, and carefully controlled conditions, including slow and steady jacking operations. Dead Load computations shall include any temporary supports such as falsework and formwork or devices such as external PT if present and carried by the span. If a rigorous structural analysis allowing for the three-dimensional effects of inadvertent twist during transportation as detailed in Section 3.1.2.3 is undertaken and included, the service load handling impact factor may be reduced to 1.05. No factored loads shall be used for deflection calculations.

3. UDOT does not allow permanent distortion (twist) as a result of relocating bridges using SPMTs.
4. Contract Documents shall include a completed table of “anticipated deflections” as discussed in LRFD Section 3.4.2.2. Deflections should incorporate those detailed in Section 3.1.2. See UDOT Go-By sheet #3.
5. Plan notes for construction loads shall include “the magnitude and location” as outlined in LRFD Section C3.4.2.1. The note shall also state the allowance for loads while supported on the SPMT. The 15% service load factor stipulated above does not apply to the Heavy lifter assembly itself or to any deflections.
6. The bridge is not subject to seismic loadings (Extreme Event Limit State) while under construction.
7. The bridge is not subject to Service III limit state while under construction. Bridges analyzed carrying construction equipment including SPMTs shall utilize Service I and not Service III with a 5% impact factor.

b. **LRFD Section 4.5 Mathematical Modeling** This section provides general guidance for mathematical modeling of bridges. The following additional requirements are extended to apply to launched and relocated spans using SPMTs.
   1. Bridge structures to be relocated are to be analyzed based on elastic behavior.
   2. For bridges launched or relocated, UDOT does not allow the construction of “continuous composite barrier” as discussed in the second paragraph of LRFD Section 4.5.1.
   3. A refined analysis is not required for spans that meet the requirements for basic beam analysis in Sections 3.1.1.e.2 and 3.1.1.g.
   4. Contract Plans shall state that all formwork for the deck shall be supported from the longitudinal girders similar to conventional construction methods. No composite Dead Load designs as discussed in the Appendix E of the FHWA 2007 reference are to be used. UDOT requires deck replacement without the use of shoring.

c. **LRFD Section 4.5.2.2 Elastic Behavior** This section outlines the basic premise that bridge structures are to be analyzed using elastic behavior. The following additional requirements are extended to apply to launched and relocated spans using SPMTs.
   1. UDOT does not allow inelastic analysis or behavior for bridges that are relocated.
   2. Inelastic analysis is only allowed for Extreme Event loading with the bridge in its final location.

d. **LRFD Section 5.5.3.4. Welded or Mechanical Splices of Reinforcement** This section addresses requirements for special grouted connection shown in Go-By sheet #5 as a post installation barrier connection detail.
   1. The longitudinal reinforcement should be continuous (LRFD A13.3) to meet NCHRP350 as described in LRFD C13.7.3.
   2. Separate requirements address areas where longitudinal reinforcement is broken in each section of barrier and will be treated as an end condition as described by LRFD Figure CA134.3.1-2.

e. **LRFD Section 5.7.3.4. Control of Cracking by Distribution of Reinforcement** This section addresses requirements for all reinforced concrete members. It is extended to apply to launched and relocated spans using SPMTs.

1. The longitudinal reinforcement in the deck and superimposed attached items like sidewalks, parapets and traffic railings shall be analyzed.
2. For the Service I load combination in Exposed Reinforced Concrete Decks, the provisions of LRFD Article 5.7.3.4 shall apply when no protective overlay is placed at the time of construction. These requirements may be waived if the structure meets the allowable stress in the concrete for the basic beam analysis in Section 3.1.1.g.
3. This criterion is a Service Limit State check. It is not required for spans that are to be removed and demolished.

f. **LRFD Section 5.9.4.2.1 Compression Stresses** This section addresses compression stresses in Prestressed Concrete members. It is extended to apply to launched and relocated spans using SPMTs.

LRFD Table 5.9.4.2.1-1 the fourth bullet shall apply to prestressed I-girder bridges launched or relocated using SPMTs with a $\Phi_w = 1.0$. Slenderness ratio computations for Φ_w may be required for box girder bridges.

g. **LRFD Section 5.9.4.2.2 Tension Stresses** This section addresses tension stresses in Prestressed Concrete. It is extended to apply to launched and relocated spans using SPMTs.

Prestressing losses may be calculated by either the Approximate or Refined methods in AASHTO LRFD Articles 5.9.5.3 and 5.9.5.4.

Service III is for tension limits subject to normal anticipated highway "traffic loading". These loadings do not include nor do they apply to construction vehicles. Use Service I for construction loadings. During design, the actual scheduling of construction is not known. Since the age of the members can have a significant effect on the stresses early on, conservative assumptions must be made to insure that the design stresses are for the worst case scenario.

For bridge decks without overlays:

Limit the outer fiber concrete flexural stress in the concrete to $0.095\sqrt{\mathbf{f'_{ci}}}$ (KSI). Protected Reinforced Concrete Decks that accidently exceed these tensile service limits shall receive a coat of methyl-methacrylate or approved penetrant sealers before the specified protected overlay is installed.

For bridge decks with overlays:

For basic beam analysis (described in Section 3.1.1.a.2), the outer fiber concrete flexural stress in the concrete may not exceed $0.125\sqrt{\mathbf{f'_{ci}}}$ (KSI). If a more rigorous analysis is made, including three-dimensional effects for inadvertent bridge twisting while in transit, the allowable stress in the concrete may increase to $0.19\sqrt{\mathbf{f'_{ci}}}$ (KSI). For the purpose of this Section, elements that have a calculated fiber stress above these provisions shall be deemed to have cracked, regardless of whether cracks actually occur or not. The respective areas affected shall be considered as cracked and shall be treated in accordance with mitigation techniques specified on the Go-By sheet #5. The plans shall denote elements and an approximate area anticipated for treatment. The loading shall include service load factor in accordance with Section 3.1.1.a.2 of this document. Spans with planned overlays may not require epoxy injection. See page Contract Specifications for crack with information and treatment.

h. **LRFD Section 5.12 Durability** This section is expanded to delineate that different durability strategies exist for bridge decks. Long term performance is directly related to the stresses induced in the bridge span and the environmental exposure. The following definitions are used to apply requirements highlighted in this section to launched and relocated spans using SPMTs.
   1. Exposed Decks are reinforced deck slabs that have no overlay at the time the structure is placed into service. These maybe CIP Slab or Tee bridges, Precast pre-tensioned concrete or steel girder structures.
   2. Protected Slabs are decks that have an overlay placed on the bridge after it is launched or placed into the final position. This maybe an asphalt or concrete expendable protective wearing surface that is considered as added dead load and not having structural capabilities.
   3. Prestressed Decks maybe pretensioned or post-tensioned. This includes beams or boxes that cannot have the deck removed without costly operations. This also includes full depth precast deck panels that are post-tensioned.

i. **LRFD Section 5.14.1.2.1 Preservice Condition** This section is expanded as follows:
   1. This AASHTO sub-section is generally addressing the handling of girders for conventional erection methods.
   2. This code provision does not apply to relocating bridges using SPMTs.
   3. This code provision does not waive any structural code requirements that the EOR, Bridge Contractor, or the Bridge Specialty Engineer meet industry standards.

j. **LRFD Section 5.14.2.3.3 Construction Load Combinations at the Service Limit State** This section addresses bridges built by the segmental method. It is hereby extended to:
   1. Prestressed Box girder structures where the top slab is the riding surface and relocated using SPMTs.
   2. Girder structures constructed with full depth prestressed deck panels without an overlay and launched or relocated using SPMTs.
   3. Construction load compression stresses are limited to 0.6 Fci.

k. **LRFD Section 6.7.4.1 Diaphragms and Cross frames** (General) This section addresses the location of diaphragms and cross frames in steel structures. The following additional requirements are extended to apply to launched and relocated spans using SPMTs.
   1. The supports where the SPMT assembly lifts the structure shall be considered an interior support.
   2. At interior supports provide either a diaphragm or a cross-frame with necessary stiffeners as appropriate for bracing, connections and local bearing. The designer should address suitable diaphragm or cross-frame details to provide the necessary comression flange stability under temporary SPMT cantilevered support conditions"

l. **LRFD Section 6.10.1.1.1a Sequence of loading** This section addresses loads applied to a steel structure. The following additional requirements are extended to apply to launched and relocated spans using SPMTs.
   1. Shored construction as allowed in the last sentence of this section is not allowed for spans relocated using SPMTs. While this section is permitted, Section C6.10.1.1.1a does not recommend use.
   2. Contract Plans shall state that forming and shoring of the deck shall be supported from the longitudinal girders similar to convention construction methods.

m. **LRFD Section 6.10.1.7 Minimum Negative Flexure Concrete Deck Reinforcement** This section addresses tensile stresses in concrete decks due to either the factored construction loads or Load Combination Service II to steel structures. An alternate to this method not requiring an overlay at the time of construction is found in section e (LRFD 5.7.3.4) which does not require an overlay at the time of construction. The article is extended to include barriers cast prior to structure movement and bridges with concrete I-beams. If this method is utilized, the designer shall note on the plans that the contractor shall anticipate cracks in the deck and barriers. The deck and barriers shall receive a coat of methyl-methacrylate or an approved penetrant sealer and then a specified protected overlay shall be installed on the deck. Consult the Construction Specifications for correct repair based on crack width.

n. **LRFD Section 9.7.2 Empirical Design (**decks) This section relates "exclusively to the empirical design process for concrete deck slabs supported by longitudinal components…" The following additional requirements are extended to apply to launched and relocated spans using SPMTs.
   1. Spans relocated with decks designed using LRFD Article 9.7.2 shall have a tension of 0 ksi.
   2. Trial runs indicate two 1-3/8" high strength PT Bar stressed to 50% Fpu on each side of each beam line may provide adequate forces to keep a deck in compression. This should be verified for each individual bridge geometry and moving condition. The level of 50% of the ultimate strength (fpu) allows for limited re-use of the temporary PT bars. If such temporary PT bars are not to be reused, then the temporary stress may be increased up to 70%, requiring fewer bars. These temporary PT bar stress levels are taken from common practice in the segmental bridge industry. It is recommended that the Designer refer to suppliers

of PT bar for further information, as necessary for his particular application. The plan notes on the Go-Bys provide this guidance.

3. With permission from UDOT, designer may wave 0 ksi stress limit state on empirical decks, but must meet section e (LRFD section 5.7.3.4) for crack control.

3.1.2 Stress and Deflection Computations to Control Integrity of Span During Lifting and Transportation

The above LRFD sections are highlighted as considerations for the EOR and his responsibilities. The delivery of the superstructure by SPMT does not waive or change the long term performance expectations of the in-service structure.

The following geometric twist controls apply only to simple span steel or concrete beam bridges with cast in place deck slabs and diaphragms and for skew angles less than 20 degrees. The EOR will have to define geometric twist controls suitable for spans with greater skews and/or movements of a multiple span structure.

3.1.2.1 Anticipated Deflections

For decks comprised of reinforced concrete slabs on steel or prestressed concrete beams, for the purposes of monitoring the structure under construction, lifting, transportation and setting in the final location, it is recommended that the EOR determine the anticipated deflection profile for the following conditions:

- Under the self weight (and prestress) of the beams when spanning the temporary supports in the BSA.
- Under the weight of cast-in-place diaphragms and formwork when spanning the temporary supports.
- Under the initial (wet) weight of cast-in-place deck slab and build-up concrete when spanning the temporary supports.
- Of the composite superstructure under hardened slab conditions, after removing the weight of any forms, and with addition of superimposed dead load from barriers, parapets, medians or sidewalks just before the superstructure is lifted for transportation while it yet remains on the temporary supports (this is the initial "*Before Lift*" condition).
- Under all the applicable structural and superimposed dead loads when the superstructure is lifted by SPMT equipment at the assumed lifting locations (this is the initial *"After-Lift"* condition).
- In the final condition in-place in the structure (it is expected that this would be the same as that of the "Before Lift" condition).
- For all the above, for precast prestressed or post-tensioned beams, take into account the age (maturity) of the concrete at the time the operation is assumed to take place.

The above deflection conditions can be calculated using any appropriate calculation technique based upon elastic analysis.

3.1.2.2 Deflection under Lift and Transportation

Under lifting by the SPMT System, (absent any Twist Distortion, discussed below) the ends of the superstructure span will deflect downward and the mid-span will deflect upwards (relative to its as-constructed profile) because of the negative flexure induced over the SPMT support locations.

Under the initial lift condition, make sure that the anticipated flexural tensile stress induced in the top of the structural concrete slab for the assumed support locations is no greater than 0.125 or 0.19√f'ci (ksi) as per Section 3.1.1.g where f'ci = anticipated strength of concrete at the time of the initial lift operation (where f'ci is assumed to be less than f'c 28 day).

If the tensile stress in the structural concrete slab exceeds the allowable value, ensure that sufficient reinforcement is provided to carry all of the anticipated tensile force at an assumed stress level of 0.5 fy up to 30ksi and that the spacing of the reinforcement in tension during lifting and transportation satisfies LRFD 5.7.3.4 as modified by Section 3.1.1.e.

If the above conditions cannot be satisfied, then it is recommended that the assumed locations of the lifting points be revised. Show any corresponding changes or necessary constraints on field operations on the Contract Plans.

For the condition corresponding to the assumed lifting that induces the above maximum allowable flexural tensile stress, calculate the anticipated "Deflection Change" - defined as the downward deflection of the ends of the span relative to a point at mid-span resulting from the change in deflected profiles from just before to just after lifting with the SPMT. Based upon knowledge of engineering materials, design assumptions and likely variations for actual conditions; estimate a corresponding tolerable range for the anticipated Deflection Change.

In order to aid on-site checking and monitoring, provide the following information on the Contract Plans:

1. The locations and elastic stiffness of the SPMT supports assumed in the design.
2. The elastic material and section properties of the superstructure span assumed in the design.
3. The anticipated deflected profile of the superstructure for the condition immediately before and immediately after lifting with the SPMT. These are referred to as the "Before Lift" and "After Lift" conditions.
4. Provide this deflected profile at a minimum of five locations across the span: at each end (over the permanent bearings), at the center of each SPMT support location and at mid-span.
5. In particular, provide the anticipated "Deflection Change" (the downward deflection of the ends of the span relative to a point at mid-span resulting from the change in deflected profiles from the "Before Lift" to "After Lift" conditions and the anticipated tolerable range. (This Deflection Change is for on-site monitoring purposes during lifting and transportation operations.)

3.1.2.3 Twist Distortion under Lift and Transportation

Under SPMT lift and transportation conditions, it is anticipated that the superstructure will experience a variety of local deflections and distortions. (Deflection is addressed above.)

Distortion due to twist might range from a global twist of the deck surface induced by non-parallel supports to a local loss of support under a beam or corner or similar circumstance.

For lifting and transportation purposes and to aid on-site monitoring, provide on the Contract Plans, the allowable Maximum Twist distortion the superstructure span can structurally tolerate. The structurally tolerable limit may be determined by any appropriate calculation technique, based on elastic theory that provides tensile stresses in the structure while being lifted and moved that might induce damage - such as cracking - at susceptible locations. Under moving operations, this might involve a combination of tensile stress due to flexural deflection (above) and due to distortion from twist. The EOR should decide upon the circumstances and acceptable limits.

On the Plans, state the allowable Maximum Twist in terms of the amount (in decimal feet) that one corner of the span may deflect up or down relative to the plane defined by the other three corners. Provide this for two separate locations as follows:

Location B (bearings) - in this case, the corners for checking twist are points located on the deck surface above the center of each edge beam at the centerline of the temporary (and permanent) support bearings. It is recommended that regardless of any calculated structural limit, this value not exceed the lesser of 0.25 feet or W/200 where W is the perpendicular distance between centers of edge beams.

Location S (SPMT Supports) - in this case, the corners for checking twist are points located on the deck surface above the centerline of each edge beam at the centerlines of supports of the SPMT support system. It is recommended that regardless of any calculated structural limit, this value not exceed the lesser of 0.16 feet or W/300 where W is the perpendicular distance between centers of edge beams.

During lift and transportation, when the superstructure span is supported by the SPMT supports, “Twist Distortion” should not be allowed to exceed the most stringent of the above limits when measured at Location B and at Location S. In this regard, the allowable Maximum Twist should be expressed as one decimal foot value for Location B and one value for Location S and noted in the plans (see Go-by #3). These analyses shall be consistent with the analysis assumptions discussed above. If the SPMT Firm’s means and methods do not allow for a sufficiently rigid support while being lifted by the SPMT so that the supports in a transverse direction do not remain linear, then the more rigorous three-dimensional analysis must be preformed with allowance for this local bending.

3.1.2.4 Directions to Contractor by Plan Notes

In order to facilitate on-site checking and monitoring, place notes on the Contract Plans as shown on Go-By #4 and the Manual for the Moving of Utah Bridges Using SPMTs.

In order to ensure the integrity of the structure and avoid or minimize potential damage during lifting, transportation and placement, a checking and monitoring system, approved by the Owner, is required. Monitoring of deflections is recommended in this manual due to the relative ease and real-time observable data that it provides. However, an alternate method of monitoring stresses by strain gauges or other means may be submitted for approval to UDOT. The following steps are considered the minimum necessary key features of the recommended checking and monitoring system:

1. For the purpose of on-site checking and monitoring, provide small permanent stainless steel bolts, rivets or inserts set into and just flush with or slightly below the surface of the deck concrete on the centerlines of the edge beams and establish a minimum of ten (10) elevation reference points at the following locations: over the permanent Bearings (Locations B = 4 points), over the center of each SPMT Support (Locations S = 4 points) and at mid-span (= 2 points for a total of 10 reference points altogether).
2. Using benchmarks in the BSA, observe and record elevations of these ten reference points in the condition just prior to lifting the superstructure (the initial "Before Lift" condition). Also, calculate the elevations relative to each other by using as a reference the average elevation of two diagonally opposite corners over the bearings.
3. Observe and record these ten reference elevations again immediately after lifting the superstructure and transferring all load to the SPMT system (the initial "After Lift" condition). Calculate the elevations relative to each other by using as a reference the (lifted) average elevation of the same two diagonally opposite corners over the bearings.
4. Using the relative elevations from the After Lift and Before Lift conditions, check for twist of the span induced by lifting. Prior to moving the span, adjust jacks and controls of the SPMT system to remove or minimize as much as possible any induced twist. In any event, ensure twist is less than the specified allowable tolerance for transportation.
5. After removing or minimizing the twist, observe the reference elevations again and calculate the change in deflection profile (in particular the "Deflection Change" or downward deflection of the ends of the span relative to mid-span) induced by lifting operations so far. Check that this Deflection Change agrees with that given on the Plans, within the specified tolerable limits.
6. Retain a permanent record of all elevations taken just before and just after the initial lift for reference. Continue the process as and when necessary throughout subsequent transportation and for final setting of superstructure in the bridge.
7. During transportation, check that the relative elevations of the ten reference points agree with the relative elevations just after the span was initially lifted in the BSA (After Lift), within the specified allowable tolerances for Maximum Twist and Maximum Deflection during Transportation.
8. After the span has been finally set in place in the bridge on the permanent bearings, check that the relative elevations of the ten reference points (Final Setting) agree with the relative elevations just before the span was initially lifted (Before Lift) in the BSA, within specified allowable tolerances after erection. {End Plan Note}

To calculate distance from a point (P_4) to a plane defined by three other non-linear points (P_1, P_2, P_3) follow the steps below:

1. First find a vector normal to the plane by taking a cross-product of vectors P_1P_2 x P_1P_3. This vector should be in the form $N = a_i + b_j + b_k$.
2. The plane is defined as $Ax + By + Cz = D$. Substitute the coefficients from the normal vector for those in the plainer vector (A=a, B=b, C=c) and use the definition of P_1 for the x, y and z (if P_1=x_1, y_1, z_1 then $x=x_1$, $y=y_1$, and $z=z_1$).
3. Next define a vector from P_4 to any point on the plane.
4. The distance from P_4 to the plain is the length of the dot product of the vector from step three (V) to the vector N normalized to a unit vector ($\left|\underset{V}{\longrightarrow}\cdot\frac{N}{|N|}\right|$).

The above approach applies to a general use regardless of skew. For the purposes of application in the field, such procedures are usually simplified - as offered in the procedures and example spreadsheets in Chapter 7 of this document - particularly for simple single spans and structures with small skews.

3.1.2.5 Instructions to Engineer of Record

At locations of interest along the span at a minimum including but not necessarily limited to those at permanent bearings, mid-span and centers of SPMT supports, take into account the following sequence of steps and time intervals and provide the required information on the Contract Plans:

1. For Prestressed Girder at Transfer (at time "t_i") provide:
    - Initial Prestress Force (P i).
    - Fiber stresses for Initial Prestress Force (P_i) and Self Weight of Girder.
    - Separate and combined deflection profiles for initial prestress and self weight (combination is usually a net upward camber).

2. Period from Transfer to Erection of Girder on Temporary Staging (at time t_{ii}), evaluate loss of prestress (from creep, shrinkage and relaxation) to determine intermediate prestress force (P_{ii}) and provide:
   Intermediate Prestress Force (P_{ii}).
    - Fiber stresses for Intermediate Prestress P_{ii} and Self Weight of Girder.
    - Intermediate deflection profile (usually a net "camber growth").

3. Pour Deck Slab and Diaphragms etc. (at time t_{iii}), consider weight of forms and wet concrete acting on non-composite girder and provide:
    - Prestress force (P_{iii}) (if different from (P_{ii}) - e.g. by introduction of Post Tensioning).
    - Fiber stresses (at top and bottom of girder, both separate and sum).
    - Deflection profile (both separate and sum so far).

4. Deck Slab Curing, Add Barriers etc (to time t_{iv}) just "BEFORE LIFT".
   Acting on the composite section, consider removal of forms, weight of barriers or other superimposed dead load, estimate additional loss of prestress (from creep, shrinkage, relaxation, if any) estimate differential shrinkage effect (if any) and provide:
    - Prestress force (P_{iv}) (if different - e.g. by introduction of PT).
    - Fiber stresses (at top of slab, top of girder, bottom of girder, separate and sum).
    - Deflection profile (separate and sum) just "Before Lift".

5. Transfer of Load to SPMT Support Locations (time t_v) just "AFTER LIFT".
   Acting on the composite section consider new support locations per SPMT concept, take into account redistributed load effects and provide:
    - Fiber stresses (at top of slab, top of girder, bottom of girder).
    - Deflection profile just "After Lift".
    - "Lift Change in Deflection Profile" from just Before Lift to just After Lift.

In addition to the above step-by-step information, in order to facilitate monitoring and control of deflections or deformations during transportation, also determine the following:

6. Determine acceptable limits for "Change in Deflection Profile" from just Before Lift to just After Lift (i.e. end of above Step 5) based on acceptable level of tensile stress defined in Section 3.1.1.e, f and g over SPMT supports. Show this as the "Acceptable Lift Change in Deflection Profile" from just Before Lift to just After Lift.
(This is not the same as that at the end of Step 5. In fact, if the "Lift Change in Deflection Profile" from Step 5 is not less than this "Acceptable Change" then the locations of the SPMT lift points should be re-considered).

7. Determine acceptable limit for "Structural Twist" of the whole deck depending on the acceptable level of tensile stress defined in Section 3.1.1.e, f and g or that which induces unnecessary separation at cast-in-place joints or mating surfaces to girders, as a result of one corner of the superstructure being deflected upwards or downwards from its un-deformed condition relative to the un-deformed plane defined by the other three corners. In the case where the basic beam analysis is used, the maximum allowable twist as defined in Section 3.1.2.3 should be the limit.
   - Show limit of "Structural Twist" on Contract Plans.
   - In any event, limit "Structural Twist" to a tolerance given by the lesser of W/200 (or 0.25ft) if measured at main bearings or W/300 (or 0.16ft) if measured at SPMT supports where W = perpendicular width between edge girders. In bridges with highly skewed decks, supports should be run parallel to the end bents and not parallel to the span direction. In these cases a more refined analysis which takes into account the three dimensional bridge layout should be conducted.

8. Consider the potential magnitude of tensile (cracking) stress likely to be induced in barriers and medians at the location of the SPMT supports. Avoid potential cracks by providing details for joints, coupling or splicing of longitudinal reinforcing bars to be completed after the superstructure has been set in its final location and no longer subject to such negative effects.

9. Determine and specify on the Plans, acceptable limits for tolerances for matching as-built beam soffit elevations and slopes to required top of bearing elevations and slopes in the final structure location. Consider effects of differential mismatch of extreme tolerances and provide means to accommodate differences in the field by the use of shims, injected high-strength grout or similar techniques. Take into account similar tolerances for setting and securing anchor bolts.

3.2 Standards and Go-By's

Information to be shown on the Contract Plans for use of SPMT construction:

Sheet 1 of the Go-Bys will denote the Staging Area, Temporary Supports and Assumed SPMT Locations

Information may involve the following: General Notes, Scope, Typical Roles and Responsibilities of Designer (EOR), Contractor, Heavy Haul/Lifter, Specialty Engineer and Shop Drawing Requirements. These basic requirements could also layout the basic issues of the design standards, equipment standards and definitions. It must be stated and understood that the means and methods of movement used in design provide one feasible method. The contractor will fully develop the erection procedure and certify the TP geometry and support conditions or may even propose an alternate method for approval. Also define the process required in the event of an unanticipated overstress causing a review of the defective component or system.

A conceptual plan layout of the anticipated staging area will show the assumed locations of the temporary supports for the beams during fabrication of the superstructure span. For this purpose, assume that beams rest on temporary supports at the same span length and width arrangement as the completed structure. The Bridge Contractor's Specialty Engineer will work with the Bridge Contractor to develop the foundation and support system as part of his shop drawing requirements. The Contract Plans should allow a spread footing to be placed or cast in the BSA with a footprint equal to each spans dimensions with a four foot increase in all directions.

Provide the elevations of the temporary supports relative to a local datum for the staging area. Also show clearances assumed from the underside of beams to the ground surface for the purpose of accommodating SPMT equipment. The actual clearances are the responsibility of the contractor. He will control the actual grading of the site and the decision to cast the span at the setting height or contract the SPMT Firm to lift the span to the setting height. Information may include global issues such as the geometry of enveloped transporters (Kamag, Goldholfer, Scheuerle, etc.), travel restrictions and concepts for flanking erections.

Sheet 2: The EOR in the DBB delivery will state the assumed plan locations of lifting points when the SPMT system is in place under the completed superstructure. It should be understood that increasing the cantilever overhangs and closing the distance between the pick points will decrease stability and increase the dynamic response of the structure. These things must be taken into account if the span is to be picked up closer than 15 feet or further than 20% of the span length from the centerlines of the temporary beam supports. Also included in sheet 2 is the lifting systems concept and requirements for each party. Sheet 2 also addresses if the contractor elects not to lift the bridge and cast the bridge at the setting height. The notes also address the supporting of a span removed for demolition.

Sheet 3: Information shall include the anticipated temporary erection stresses in the bridge structure. A schematic showing setting height, weight, assumed modulus of elasticity, assumed inertia, maximum out of plane deformation at the centerline of SPMT supports and at the centerline of final supports may include stability frames/towers, operating safety factors, and salutation of industry standards by reference.

Sheet 4: Information includes movement system concept and monitoring notes.

Sheets 5: Information may include miscellaneous optional requirements for improving/augmenting the operational plan such as attaching the bearing pads, delayed or fused barrier walls, the use of closure pours, the optional use and allowance of temporary post tensioning, and any anticipated crack sealing. The EOR should add other contingency features such as shim plates, etc.

Sheet 6: Address excessive grades and the use of auxiliary hydraulic systems.

Sheet 7: Address the use of a span carrier for drop down replacement and removal concepts. The EOR is just showing a concept and the anticipated gross and net weights. The Contractor's Bridge Specialty Engineer and the Heavy Lifter will work submit the contractors selected system for review and approval. The Construction specifications establish the measurement of acceptance. This criterion is based on handling stresses and the control of twist/distortion during all movement.

3.3 Checklists for EOR

Design Checklists:

- Did the slab exceed allowable stresses as defined in Section 3.1.1.e, f and g for Fci' and steel?
- Did the analysis utilize an appropriate transform section?
- Did the designer calculate the weights using accurate practices? Or estimate and state the methods of estimation on the plans so the Contractor's Specialty Engineer may calculate them?

Plans Checklist:

- Did the EOR note on the plans that the Contractor's Specialty Engineer will design the temporary support in the BSA?
- Is the BSA with the limits of the project? Are there any noise constraints at the BSA?
- Are there notes and specifications covering pointing and patching like paint touch up on the plans?

3.4 References

UDOT 2008: *Standard Specifications for Road and Bridge Construction*, Utah Department of Transportation, 2008

UDOT 2008: *Structures Design Manual,* Utah Department of Transportation, 2008

FHWA 2007: *Manual on Use of Self-Propelled Modular Transporters to Move Bridges*, Publication No. FHWA-HIF-07-022

FHWA 2006: *Decision-Making Framework for PREFABRICATED BRIDGE ELEMENTS and SYSTEMS (PBES)*, Publication No. FHWA-HIF-06-030.

AASHTO 2007: *AASHTO LRFD Bridge Design Specifications,* 4th Edition, LRFD, American Association of State Highway and Transportation Officials, Washington, DC.

FHWA/AASHTO 2004 International Technology Exchange Program Scan Trip on *Prefabricated Bridge Elements and Systems in Japan and Europe*, Report Number FHWA-PL-05-003, March 2005

FDOT 2006: "Graves Avenue over SR 400 (I-4)" Florida Department of Transportation, February 2006

3.5 SPMT - Deflection Change and Required Jack Stroke

The designer (EOR) should calculate the anticipated deflected shape of the superstructure for the support conditions and loads just before and just after lifting by the SPMT in order to determine the change in deflection profile and the minimum jacking stroke required by the SPMT System to clear the bearings. For the most common types of beam and slab superstructure, these are likely to be small - a matter of less than an inch to an inch or so. They depend upon the flexibility of the superstructure and the change in support locations under the same, constant, loads. The designer may use any convenient method of structural analysis to calculate deflections. For simply-supported, statically determinate conditions, classical analysis using familiar elastic techniques such as slope-deflection, moment-area or strain energy are appropriate. Alternatively, most structural analysis computer programs also provide deflections.

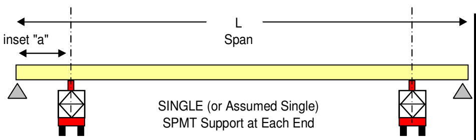
For the case of a simply-supported span, the change in deflection profile depends only upon the change in support locations from being at the ends to the SPMT supports. If it is assumed that the SPMT supports are single supports located at the center of SPMT system at the same distance, "a", from each end bearing, then the analysis is statically determinate. If there are two SPMT supports at each end of the span, separated by a short spacing, "s", and if these support reactions are hydraulically equalized - as is the case for most SPMT operations - then the analysis is again statically determinate. For statically determinate conditions, the change in deflection profile depends upon the weight (W) and stiffness (EI) of the span, span (L) and the shift in support locations.

Two utility spreadsheets are provided for the case of either a single SPMT support under each end or for a pair of symmetrical, equally loaded, SPMT supports under each end. While this manual does not require that the span be lifted on supports symmetrical about the axis, it is believed that this is the common method and as a result, the spreadsheets are tailored to this condition. These spreadsheets take as input data only the span length (L), assumed modulus of elasticity (E), inertia (I), total span weight (W), the inset from each end to the centerline of the SPMT (a) and the spacing (s) of the SPMT supports. Calculation of deflections is based upon the "moment-area" technique applied to the "before" and "after" lift support locations. The difference gives the "Deflection Change", relative to the tangent at mid-span, and from this, the minimum "Jack Stroke" required to lift just to clear the bearings. The Jack Stroke to clear the bearings is small (less than an inch or so). It does not represent in any way the total jacking needed to begin moving the SPMT - which may need a foot or more to clear obstacles. Rather the "Deflection Change" relative to mid-span, represents the order of magnitude deflection difference likely to be expected or measured in the field from just before to just after lifting. If so desired, the Deflection Change and anticipated minimum Jack Stroke can be monitored by elevation surveys of the deck during SPMT jacking. This affords an opportunity for practical field monitoring and has been built into the on-site SPMT move monitoring spreadsheets under Chapter 7.

This method and the accompanying spreadsheets are verified by three dimensional analyses in the following section.

SPMT - DEFLECTION CHANGE and JACK STROKE CALCULATIONS

Enter Data in Blue on Yellow ONLY !								
Span L =	140.00 ft	L =	140.00	L =	140.00	L =	140.00	
SPMT inset "a" CL =	14.00 ft	a =	14.00	a =	14.00	a =	14.00	
l = (L - 2a) =	112.00 ft	*l* =	112.00	*l* =	112.00	*l* =	112.00	
n = a / (L-2a) =	0.1250 ratio	n =	0.1250	n =	0.1250	n =	0.1250	
E concrete =	636,000 KSF							
Inertia = I =	628.0 ft^4	EI =	399,408,000.00	EI =	399,408,000.00	EI =	399,408,000.00	Kft^2
Total Weight = W =	2,440.00 Kips							
unit wt = w = W/L =	17.4286 Kkip/ft	w =	17.4286	w =	17.4286	w =	17.4286	



SPMT - Symmetrical

LIMITATIONS:
This spreadsheet uses Moment Area deflection theory to calculate the required jack stroke
It does so by considering the change that occurs by shifting support locations from the end bearings of the span to the SPMT supports
Intermediate calculation steps do NOT represent absolute deflections or cambers
The final "Jack Stroke" result is theoretically valid for this situation

		Deflection at Bearings		Deflection at At CL SPMT supports		Deflection at Midspan	
RESULTS	**Relative to Mid-Span, DEFLECTION CHANGE =**	**0.103**	**Feet**	**0.067**	**Feet**	**0.000**	**Feet**

Min JACK STROKE REQD to Clear BRGS = Defln Change at BRGS - Defln Change at SPMT = 0.036 Ft = 0.44 ins at SPMT Support

Self Weight Simple Span on BRGS:

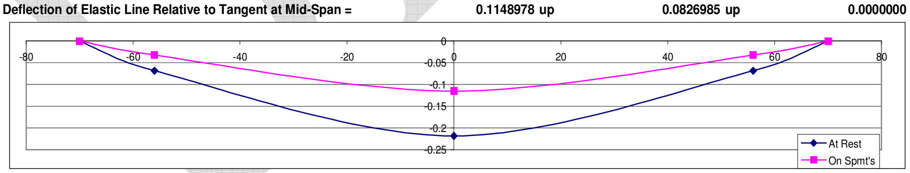
delta end brgs =	0.0000			
delta at SPMT = (w *a / (24(EI)) *(L^3 - 2La^2 + a^3) =		0.0685 down		
delta midspan = 5wL^4 / 384(EI) =			0.2183 down	
Relative to tangent at Mid-Span =	**0.2183 up**	**0.1498 up**	**0.0000 datum**	

MOMENT AREA CALCS	Reactions:		1,220.00			Kips
BEFORE:	Moment Diagram :		0.00		15,372.00	42,700.00 ft-kip
	Areas:			MidRect =	0.002155	
	Areas:	Half Parab =	0.004989	MidParab =	0.002554	
	Slope of Elastic Line Relative to Tangent at Mid-Span =		0.0049891		0.0047097	0.0000000 rads
	Lever Arm x-bar :			MidRect =	28.00	
	Lever Arm x-bar :	Half Parab =	43.75	MidParab =	35.00	
	Moment of Area :			MidRect =	0.060348	
	Moment of Area :	Half Parab =	0.218271	MidParab =	0.089404	
Deflection of Elastic Line Relative to Tangent at Mid-Span =			**0.2182710 up**		**0.1498 up**	**0.0000 ft**

Self Weight Simple Span + Cantilevers on SPMT:

delta end brgs = dE = ((w(L-2a)^3*a)/(24EI)) * { 1 - 6n^2 -3n^3 } =	0.03 up		
delta SPMT supports =		0.00	
delta midspan = dC = (wl^4 / 384EI)*{5-24n^2} =			0.08 down
Relative to tangent at Mid-Span =	0.1149 up	0.0827 up	0.0000 datum

MOMENT AREA CALCS	Reactions:				1,220.00	
AFTER:	Moment Diagram :		0.00		-1,708.00	25,620.00
	Areas:	Part Parab =	0.00	MidParab =	0.00	
	Areas:			Rect =	0.00	
	Slope of Elastic Line Relative to Tangent at Mid-Span =		0.0022950		0.0023149	0.0000000 rads
	Height of tip extrapolated from slope at SPMT =		0.03 up			
	Defln tip rel to slope at SPMT supt = wa^4/8EI =		0.00 down			
	Net defln of tip =		0.03 up			
	Lever Arm x-bar :	Part Parab =	10.50	MidParab =	35.00	
	Lever Arm x-bar :	MidParab =	49.00	Rect =	28.00	
	Lever Arm x-bar :	Rect =	42.00			
	Moment of Area :	Part Parab =	0.00			
	Moment of Area :	MidParab =	0.13	MidParab =	0.09	
	Moment of Area :	Rect =	-0.01	Rect =	-0.01	
Deflection of Elastic Line Relative to Tangent at Mid-Span =			**0.1148978 up**		**0.0826985 up**	**0.0000000 ft**



RESULTS	**BEFORE minus AFTER =**		**Checks derivation by two ways**	
Formulae :	**Relative to Mid-Span, Deflection Change =**	0.1034 down	0.0671 down	0.00 datum
Momt Area :	**Relative to Mid-Span, Deflection Change =**	**0.1034** down	**0.0671** down	**0.00** datum
		1.2405 ins down	0.8046 ins down	0.00

Total STROKE REQD to Clear BRGS = Defln Change at BRGS - Defln Change at SPMT = 0.0363 Ft = 0.44 ins At SPMT Support

STROKE Part 1 = delta Simple at SPMT =	0.0685	**Verifies consistency of spreadsheet**
STROKE Part 2 = dE = (wa/24EI) *{L^3 - 6aL^2 + 6a^2L+ a^3} =	-0.0322	
INDEPENDENT CALCULATION : Total STROKE REQD to Clear BRGS =	0.0363	**0.44 ins At SPMT Support**

APPROXIMATE FORMULA for DEFLECTION CHANGE (from example in Chapter 9)

Deflection Change = (P L^3 / 6EI) * { 3a/4L - (a/L)^3) =		**0.0908**	By elastic 3rd order curve for Point Loads		0.00 datum
where P = w L / 2	At X =	70.0000	At X =	56.0000	
	Constant = K =	0.0000		0.0000	**i.e. a CONSERVATIVE APPROACH**
		0.0908		0.0465	
APPROXIMATE FORMULA : Total STROKE REQD to Clear BRGS =		0.0443	FT		**0.53 ins At SPMT Support**

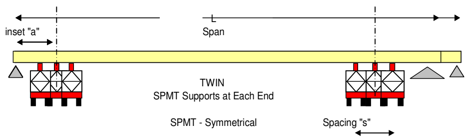
Simple CL SPMT Original by AJM March 2008

SPMT Capacities:
The minimum available vertical stroke of the SPMT platform is typically 24 inches and the vertical lift range (meaning the change in height of platform) is approximately 36 to 60 inches. For operational purposes, an available stroke of 16 to 20 inches should be assumed. The reserve stroke is good practice to account for small ground settlement.

SPMT - DEFLECTION CHANGE and JACK STROKE CALCULATIONS

Enter Data in Blue on Yellow ONLY !		
Span L =	140.00	ft
SPMT inset = a =	14.00	ft
SPMT Spacing = s =	10.00	ft
l = (L - 2a) =	112.00	ft
n = a / (L-2a) =	0.1250	ratio
E concrete =	636,000	KSF
Inertia = I =	628.0	ft^4
Total Weight = W =	2,440.00	Kips
unit wt = w = W/L =	17.4286	Kkip/ft

L =	140.00	L =	140.00	L =	140.00	L =	140.00
		a1 =	9.00	a2 =	19.00		
		l 1 =	122.00	l 2 =	102.00		
		n =	0.0738	n =	0.1863		
EI =	399.41 * 10^6 Kft^2	EI =	399.41 * 10^6 Kft^2	EI =	399.41 * 10^6 Kft^2	EI =	399.41 * 10^6 Kft^2
w =	17.4286	w =	17.4286	w =	17.43	w =	17.4286



LIMITATIONS:
This spreadsheet uses Moment Area deflection theory to calculate the required jack stroke
It does so by considering the change that occurs by shifting support locations from the
end bearings of the span to the SPMT supports
Intermediate calculation steps do NOT represent absolute deflections or cambers
The final "Jack Stroke" result is theoretically valid for this situation

RESULTS		Deflection at Bearings		Deflection at At SPMT "a1"		Deflection at At SPMT "a2"		Deflection at Midspan	
	Relative to Mid-Span, DEFLECTION CHANGE =	0.102	Feet	0.079	Feet	0.056	Feet	0.000	Feet

Average, Minimum JACK STROKE Requried to CLEAR BEARINGS = 0.035 Feet = 0.420 ins at CL SPMT supports

SIMPLY SUPPORTED FULL SPAN, L

	R brgs		M1	M2	MCL
End Reaction R =	1220	kips			
	M brgs				
Simply-Supported Bending Moment for Full Span, L =	0.0	ft kips	10,274.1	20,034.1	42,700.0

MOMENT AREA THEORY
BEFORE: Relative to tangent at Mid-Span

MCL-M2 =	22,665.9		
(L - 2*a2) / 2 =	51.00		
	Area / EI	x-bar, a2	A*xbar
Area 1/2 Parabola, MCL to M2 / EI =	1,929.45	31.88	61,501.33
Area Rectangle, MCL to M2 / EI =	2,558.14	25.50	65,232.55
Sum =	4,487.59		126,733.88

MCL-M1 =	32,425.86		
(L - 2*a1) / 2 =	61.00		
	Area / EI	x-bar, a2	A*xbar
Area 1/2 Parabola, MCL to M1 / EI =	3,301.52	38.13	125,870.26
Area Rectangle, MCL to M1 / EI =	1,569.13	30.50	47,858.44
Sum =	4,870.64		173,728.70

	Area / EI	x-bar, a2	A*xbar
Area 1/2 Parabola, for Span =	4,989.05	43.75	218,270.96

BEFORE:

	At Brgs Slope	Defln	At SPMT-1 Slope	Defln	At SPMT-2 Slope	Defln	MID-SPAN Slope	Defln
Summary for Self Weight Deflection =	4,989.05	218,270.96	4,870.64	173,728.70	4,487.59	126,733.88	0.00	0.00

Check by Comparison

	END BRGS Slope	Defln	MID-SPMT SUPPORTS Slope	Defln	MID-SPAN Slope	Defln	
Mean Values of this sheet =			4,679.12	150,231.29			**GOOD**
Check From Sheet 1 = Slope =	4,989.05		4,709.66		0.00		**AGREEMENT**
Check From Sheet 1 = Deflection =		218,270.96		149,751.34		0.00	**OK**

SPAN on SPMT SUPPORTS

ASSUMPTION is that SPMT REACTIONS are EQUALIZED

at x =	0.00	at x =	9.00	14.00	at x =	19.00	at x = 70.00
		R a1 =	610.00		R a2 =	610.00	
		L/2-a1 =	61.00		L/2-a2 =	51.00	

MOMENT AREA THEORY
AFTER:

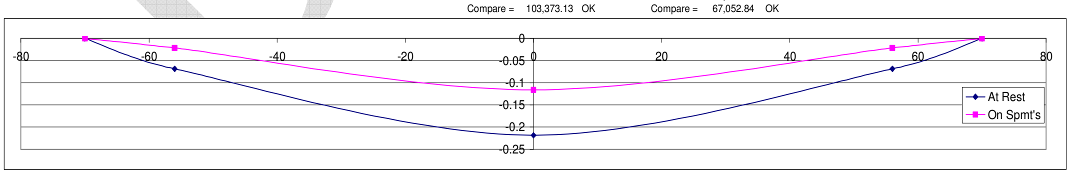
	BRGS		AT a1	AT (a1+a2)/2		At a2		AT CL	
Self Weight Moment =	0.00		-705.86	-1,708.00		-3,145.86		-42,700.00	
Reaction Moment =	0.00		0.00	3,050.00		6,100.00	= Ra1*(a2-a1)	37,210.00	= R a1(L/2 - a1)
Reaction Moment =	0.00		0.00	0.00		0.00		31,110.00	= R a2(L/2 - a2)
Moments Sum =	0.00	Sum =	-705.86	1,342.00	Sum =	2,954.14	Sum =	25,620.00	
		Av =		1,124.14					
		M at (a1+a2)/2 - Av =		217.86	= sag part of parabola				

	From BRG to a1 Area	xbar	A*xbar	From a1 to a2 Area	xbar	A*xbar	From a2 to Mid-Span Area	xbar	A*xbar	
Area Moment / EI =	0.00	0.00	0.00	-17.67	5.00	-88.36	377.21	25.50	9,618.89	Rectangle
Area Moment / EI =	0.00	0.00	0.00	73.96	6.67	493.09	0.00		0.00	Triangle
Area Moment / EI =	-5.30	6.75	-35.79	7.27	5.00	36.36	1,929.45	31.88	61,501.33	Parabola
Increment of Area and Deflection =	-5.30		-35.79	63.56		441.09	2,306.66		71,120.22	Sum
Accumulated Slope =	2,364.93			2,370.23			2,306.66			
Accumulated Deflection =		at brgs =	115,924.22		at a1 =	94,627.96		at a2 =	71,120.22	
					av a1 and a2 =	82,874.09				
					Compare =	82,698.50	OK			

AFTER:

	At Brgs Slope	Defln	At SPMT-1 Slope	Defln	At SPMT-2 Slope	Defln	MID-SPAN Slope	Defln
	2,364.93	115,924.22	2,370.23	94,627.96	2,306.66	71,120.22	0.00	0.00

BEFORE - AFTER =	2,624.12	102,346.73	2,500.42	79,100.74	2,180.93	55,613.66	0.00	0.00
			av a1 and a2 =	67,357.20				
	Compare =	103,373.13 OK	Compare =	67,052.84 OK				



RESULTS BEFORE - AFTER =	At Brgs	At SPMT-1	At SPMT-2	MID-SPAN
Relative to Mid-Span, Deflection Change (ft) =	**0.1023**	**0.0791**	**0.0556**	**0.0000**

Mean at SPMT Supports = 0.0674
Mean JACK STROKE to CLEAR BEARINGS = 0.0350 Feet = 0.42 Inches Agrees with Simple CL SPMT et al

Twin SPMT Supports Original by AJM March 2008

SPMT Capacities:
The minimum available vertical stroke of the SPMT platform is typically 24 inches and the vertical lift range (meaning the change in height of platform) is approximately 36 to 60 inches. For operational purposes, an available stroke of 16 to 20 inches shoucal stroke of the SPMT plat stroke is good practice to account for small ground settlement.

The following example is a finite element model to determine tolerable stress limits under deflection and twist. This analysis is for information purposes only. The model was used to determine the contributing stresses to each of the distortions placed upon the superstructure. This was used to establish and validate the structural requirements of this section. The EOR could generate a similar analysis and establish tighter controls during construction.

Three Dimensional Analysis of Superstructure

Four three-dimensional plate models were created to refine the analysis of the superstructure (See figure 3-2 for rendering). Since these plate models do not utilize a sequential construction staging process, the initial forces were taken from the Conspan analysis completed by IDA Consulting Engineers, Inc. on February 3, 2006 for the FDOT Grave Ave project. The four models were for the following static conditions:

- Superstructure supported near the end as constructed.
- Superstructure supported on SPMTs.
- Superstructure supported on rigid beam at the center of the SPMT support.
- Superstructure supported as before with an imposed 3” drop in one corner.

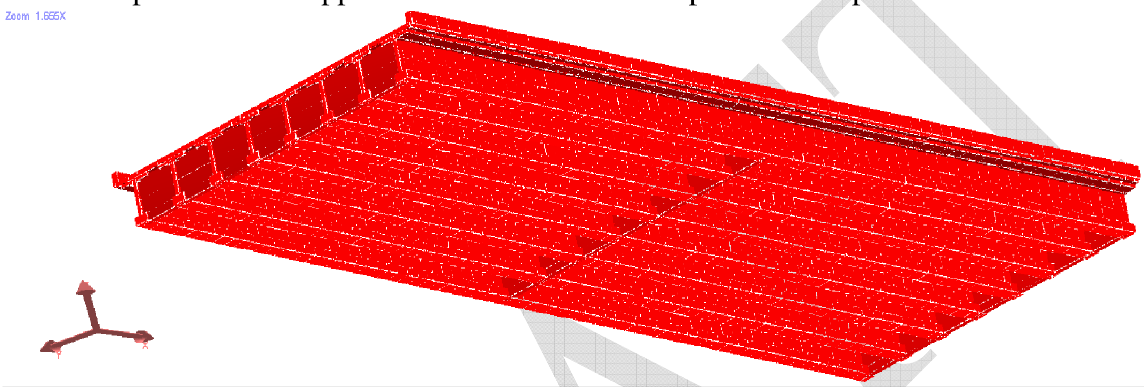


Figure 3-2 - Rendering of typical plate model

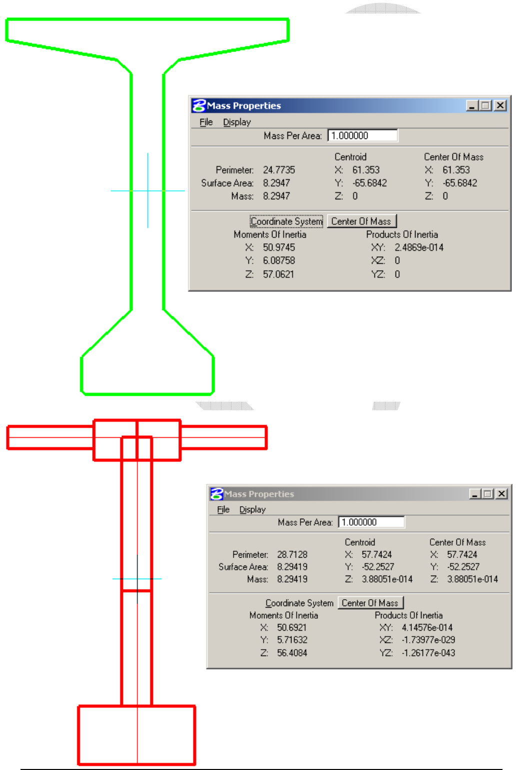


Figure 3-3 – Section Properties of the FLA Bulb Tee and the Plate Model

In order to create an accurate plate model, a series of plates had to be devised to mimic the Florida Bulb Tee Girders. The plate model should have the same area and inertia as the girder under consideration. Once that was completed, the first model could be constructed taking into account the dimensions of the superstructure (Figure 3-3).

The second model used spring supports to model the SPMT. Iteration on the spring stiffness was used to force the model to support the superstructure evenly between the two supports over each SPMT. Once the second model was completed and running properly, the stress levels could be calculated for the superstructure while supported by the SPMTs.

As mentioned earlier, the plate models in this analysis do not have construction sequencing. Therefore, the stresses in the models are not accurate; they can only be used for differential stresses. For instance, taking the difference in stress from the second model to the first model and using superposition to combine with the stress from the Conspan analysis, one can obtain the actual stresses in the superstructure when it is lifted by the SPMT. Figure 3-4 shows a graphical representation of the stresses in a plate model.

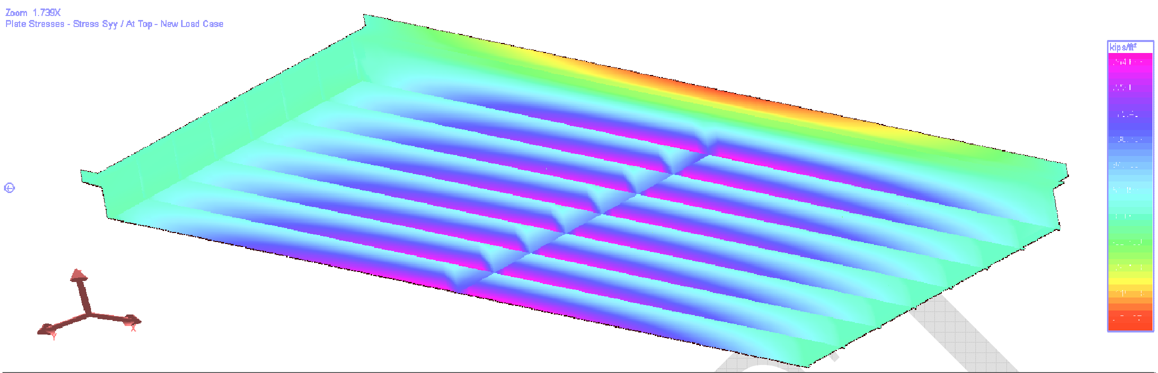


Figure 3-4 – Stresses in a plate model – note: these are not the same as the stresses in the superstructure.

In order to model an unexpected twist from the SPMTs, a third model was created that used a rigid member to support the superstructure at the center line of each SPMT support. This member could then be moved to imitate the differential movement possible while moving the superstructure. In this model, the beams must "sit" on the rigid member without being forced to twist as the member deflects.

The fourth model is much like the third with a change in support conditions that allowed one corner of the superstructure to dip 3 inches. This was accomplished by replacing one corner support with an upward force. This force was changed until the desired deflection was achieved. Figure 3-5 shows the deflected shape of the plate model.

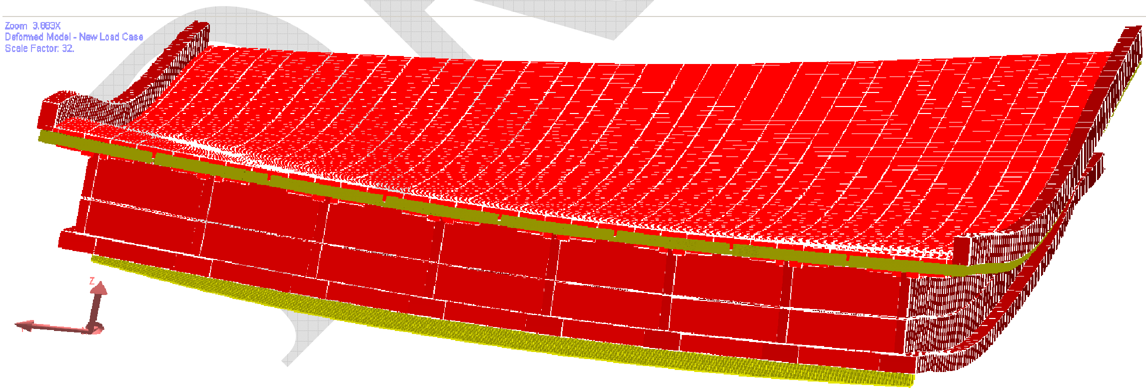


Figure 3-5 – The deflected shape of the fourth model undergoing a torque

Again it was necessary to take the stress difference in models three and four and combine using superposition with the previous stresses of the superstructure being supported by the SPMTs.

These resulting stresses were integrated over certain regions to obtain forces in composite sections at different locations along the bridge. These forces were then used to calculate longitudinal and principal stresses in the bridge. A comparison was done in insure accuracy of the model and integration methods (see table 3-1).

Distance from Bottom of Girder	Hand Calculations	Method in Spreadsheet (Interior beam)	Stresses from LARSA (Interior beam)	Method in Spreadsheet (Exterior beam)	Stresses from LARSA (Exterior beam)	**Average**
7.29	139.0 KSF	133.9 KSF	128.1 KSF	126.4 KSF	125.1 KSF	**130.5 KSF**
6.958	120.1 KSF	115.4 KSF	114.4 KSF	107.8 KSF	110.8 KSF	**113.7 KSF**
6.63	101.4 KSF	97.0 KSF	100.8 KSF	89.3 KSF	96.7 KSF	**97.1 KSF**
6.341	84.9 KSF	80.9 KSF	88.9 KSF	73.1 KSF	84.2 KSF	**82.4 KSF**
6.25	79.8 KSF	75.8 KSF	83.7 KSF	68.0 KSF	79.2 KSF	**77.3 KSF**
5.92	61.0 KSF	57.4 KSF	64.7 KSF	49.5 KSF	61.2 KSF	**58.8 KSF**
5.667	46.6 KSF	43.2 KSF	50.2 KSF	35.3 KSF	47.4 KSF	**44.5 KSF**
4.854	0.3 KSF	-2.2 KSF	3.6 KSF	-10.4 KSF	3.1 KSF	**-1.1 KSF**
4.625	-12.8 KSF	-15.0 KSF	-9.9 KSF	-23.3 KSF	-11.2 KSF	**-14.4 KSF**
3.583	-72.1 KSF	-73.2 KSF	-71.1 KSF	-81.8 KSF	-76.3 KSF	**-74.9 KSF**
2.5415	-131.4 KSF	-131.3 KSF	-132.3 KSF	-140.3 KSF	-141.4 KSF	**-135.4 KSF**
2.253	-147.9 KSF	-147.5 KSF	-149.3 KSF	-156.5 KSF	-159.4 KSF	**-152.1 KSF**
1.5	-190.8 KSF	-189.5 KSF	-195.0 KSF	-198.8 KSF	-205.6 KSF	**-195.9 KSF**
0.67	-238.0 KSF	-235.9 KSF	-245.3 KSF	-245.4 KSF	-256.6 KSF	**-244.2 KSF**
0.57	-243.7 KSF	-241.5 KSF	-251.4 KSF	-251.0 KSF	-262.7 KSF	**-250.1 KSF**
0	-276.2 KSF	-273.3 KSF	-286.0 KSF	-283.0 KSF	-297.7 KSF	**-283.2 KSF**
Pearson Product Moment Correlation (R^2 METHOD)	**0.9998**	**0.9998**	**0.9997**	**0.9998**	**0.9994**	

Table 3-1 – Comparisons of different methods of stress calculation

The following page shows some results used to substantiate the service load factor and stress limits imposed in this document.

Midspan I	Construction		Δ	On SPMT		Δ	On SPMT with Torque	
	w/ Initial Prestress Forces	w/ prestress after losses		w/ Initial Prestress Forces	w/ prestress after losses		w/ Initial Prestress Forces	w/ prestress after losses
Axial Top Slab	-117 psi	-135 psi	405 psi	288 psi	270 psi	-11 psi	277 psi	259 psi
Axial Btm Haunch	-82 psi	-20 psi	274 psi	192 psi	253 psi	29 psi	221 psi	283 psi
Axial Top Beam	-1,790 psi	-1,729 psi	274 psi	-1,516 psi	-1,455 psi	29 psi	-1,487 psi	-1,425 psi
Axial Cent Comp	-1,780 psi	-1,537 psi	-28 psi	-1,807 psi	-1,565 psi	122 psi	-1,685 psi	-1,443 psi
Axial Btm Beam	-1,753 psi	-1,046 psi	-800 psi	-2,553 psi	-1,846 psi	359 psi	-2,194 psi	-1,486 psi

Midspan IV	Construction		Δ	On SPMT		Δ	On SPMT with Torque	
	w/ Initial Prestress Forces	w/ prestress after losses		w/ Initial Prestress Forces	w/ prestress after losses		w/ Initial Prestress Forces	w/ prestress after losses
Axial Top Slab	-117 psi	-135 psi	415 psi	297 psi	280 psi	-14 psi	284 psi	266 psi
Axial Btm Haunch	-82 psi	-20 psi	292 psi	211 psi	272 psi	27 psi	238 psi	299 psi
Axial Top Beam	-1,790 psi	-1,729 psi	292 psi	-1,498 psi	-1,436 psi	27 psi	-1,471 psi	-1,409 psi
Axial Cent Comp	-1,780 psi	-1,537 psi	10 psi	-1,769 psi	-1,526 psi	121 psi	-1,649 psi	-1,406 psi
Axial Btm Beam	-1,753 psi	-1,046 psi	-711 psi	-2,464 psi	-1,757 psi	360 psi	-2,104 psi	-1,397 psi

Midspan VIII	Construction		Δ	On SPMT		Δ	On SPMT with Torque	
	w/ Initial Prestress Forces	w/ prestress after losses		w/ Initial Prestress Forces	w/ prestress after losses		w/ Initial Prestress Forces	w/ prestress after losses
Axial Top Slab	-117 psi	-135 psi	405 psi	288 psi	270 psi	11 psi	298 psi	281 psi
Axial Btm Haunch	-82 psi	-20 psi	274 psi	192 psi	253 psi	-29 psi	163 psi	224 psi
Axial Top Beam	-1,790 psi	-1,729 psi	274 psi	-1,516 psi	-1,455 psi	-29 psi	-1,546 psi	-1,484 psi
Axial Cent Comp	-1,780 psi	-1,537 psi	-28 psi	-1,807 psi	-1,565 psi	-122 psi	-1,930 psi	-1,687 psi
Axial Btm Beam	-1,753 psi	-1,046 psi	-800 psi	-2,553 psi	-1,846 psi	-359 psi	-2,912 psi	-2,205 psi

CL Temp Support I	Construction		Δ	On SPMT		Δ	On SPMT with Torque	
	w/ Initial Prestress Forces	w/ prestress after losses		w/ Initial Prestress Forces	w/ prestress after losses		w/ Initial Prestress Forces	w/ prestress after losses
Axial Top Slab	-38 psi	-13 psi	310 psi	272 psi	297 psi	-166 psi	106 psi	130 psi
Axial Btm Haunch	-26 psi	64 psi	209 psi	183 psi	273 psi	-29 psi	154 psi	244 psi
Axial Top Beam	-502 psi	-412 psi	209 psi	-292 psi	-202 psi	-29 psi	-322 psi	-231 psi
Axial Cent Comp	-1,265 psi	-1,022 psi	-23 psi	-1,288 psi	-1,045 psi	287 psi	-1,001 psi	-758 psi
Axial Btm Beam	-3,218 psi	-2,585 psi	-617 psi	-3,835 psi	-3,203 psi	1,097 psi	-2,738 psi	-2,106 psi

CL Temp Support IV	Construction		Δ	On SPMT		Δ	On SPMT with Torque	
	w/ Initial Prestress Forces	w/ prestress after losses		w/ Initial Prestress Forces	w/ prestress after losses		w/ Initial Prestress Forces	w/ prestress after losses
Axial Top Slab	-38 psi	-13 psi	380 psi	343 psi	367 psi	-131 psi	212 psi	236 psi
Axial Btm Haunch	-26 psi	64 psi	263 psi	237 psi	328 psi	1 psi	239 psi	329 psi
Axial Top Beam	-502 psi	-412 psi	263 psi	-238 psi	-148 psi	1 psi	-237 psi	-147 psi
Axial Cent Comp	-1,265 psi	-1,022 psi	-6 psi	-1,271 psi	-1,028 psi	306 psi	-965 psi	-722 psi
Axial Btm Beam	-3,218 psi	-2,585 psi	-695 psi	-3,913 psi	-3,281 psi	1,086 psi	-2,828 psi	-2,195 psi

CL Temp Support VIII	Construction		Δ	On SPMT		Δ	On SPMT with Torque	
	w/ Initial Prestress Forces	w/ prestress after losses		w/ Initial Prestress Forces	w/ prestress after losses		w/ Initial Prestress Forces	w/ prestress after losses
Axial Top Slab	-38 psi	-13 psi	310 psi	272 psi	297 psi	166 psi	439 psi	463 psi
Axial Btm Haunch	-26 psi	64 psi	209 psi	183 psi	273 psi	29 psi	212 psi	303 psi
Axial Top Beam	-502 psi	-412 psi	209 psi	-292 psi	-202 psi	29 psi	-263 psi	-173 psi
Axial Cent Comp	-1,265 psi	-1,022 psi	-23 psi	-1,288 psi	-1,045 psi	-287 psi	-1,575 psi	-1,332 psi
Axial Btm Beam	-3,218 psi	-2,585 psi	-617 psi	-3,835 psi	-3,203 psi	-1,096 psi	-4,931 psi	-4,299 psi

Note: All stresses are based on concrete transformed to 6,000psi.
To get the actual stresses in the slab multiply by sqrt(4,500)/sqrt(6,000)
Compression is negative Values

CL Temp Support I	Construction		Δ	On SPMT	0	Δ	On SPMT with Torque	
	w/ Initial prestressForces	w/ prestressafter losses		w/ Initial prestressForces	w/ prestressafter losses		w/ Initial prestressForces	w/ prestressafter losses
Shear Stress	97 psi	105 psi	-148 psi	-52 psi	-43 psi	-108 psi	-160 psi	-151 psi
Axial Stress	1,265 psi	1,022 psi	23 psi	1,288 psi	1,045 psi	-287 psi	1,001 psi	758 psi
Radius	640 psi	522 psi	6 psi	646 psi	524 psi	-121 psi	525 psi	408 psi
Principal Tension	-7 psi	-11 psi	5 psi	-2 psi	-2 psi	-23 psi	-25 psi	-29 psi

CL Temp Support IV	Construction		Δ	On SPMT		Δ	On SPMT with Torque	
	w/ Initial prestressForces	w/ prestressafter losses		w/ Initial prestressForces	w/ prestressafter losses		w/ Initial prestressForces	w/ prestressafter losses
Shear Stress	97 psi	105 psi	-116 psi	-19 psi	-10 psi	-129 psi	-148 psi	-140 psi
Axial Stress	1,265 psi	1,022 psi	6 psi	1,271 psi	1,028 psi	-306 psi	965 psi	722 psi
Radius	640 psi	522 psi	-4 psi	636 psi	514 psi	-131 psi	505 psi	387 psi
Principal Tension	-7 psi	-11 psi	7 psi	psi	psi	-22 psi	-22 psi	-26 psi

CL Temp Support VIII	Construction		Δ	On SPMT		Δ	On SPMT with Torque	
	w/ Initial prestressForces	w/ prestressafter losses		w/ Initial prestressForces	w/ prestressafter losses		w/ Initial prestressForces	w/ prestressafter losses
Shear Stress	97 psi	105 psi	-123 psi	-27 psi	-18 psi	215 psi	188 psi	197 psi
Axial Stress	1,265 psi	1,022 psi	23 psi	1,288 psi	1,045 psi	287 psi	1,575 psi	1,332 psi
Radius	640 psi	522 psi	5 psi	644 psi	523 psi	165 psi	809 psi	694 psi
Principal Tension	-7 psi	-11 psi	7 psi	-1 psi	psi	-22 psi	-22 psi	-28 psi

CL Support IV	Construction		Δ	On SPMT		Δ	On SPMT with Torque	
	w/ Initial prestressForces	w/ prestressafter losses		w/ Initial prestressForces	w/ prestressafter losses		w/ Initial prestressForces	w/ prestressafter losses
Shear Stress	124 psi	132 psi	-225 psi	-101 psi	-93 psi	4 psi	-97 psi	-88 psi
Axial Stress	720 psi	534 psi	16 psi	736 psi	550 psi	-2 psi	734 psi	547 psi
Radius	381 psi	298 psi	1 psi	382 psi	290 psi	-2 psi	380 psi	288 psi
Principal Tension	-21 psi	-31 psi	7 psi	-14 psi	-15 psi	1 psi	-13 psi	-14 psi

CL Support IV NA Girder	Construction		Δ	On SPMT		Δ	On SPMT with Torque	
	w/ Initial prestressForces	w/ prestressafter losses		w/ Initial prestressForces	w/ prestressafter losses		w/ Initial prestressForces	w/ prestressafter losses
Shear Stress	315 psi	320 psi	-112 psi	204 psi	208 psi	2 psi	206 psi	210 psi
Axial Stress	1,407 psi	1,142 psi	43 psi	1,451 psi	1,185 psi	-2 psi	1,448 psi	1,183 psi
Radius	771 psi	654 psi	-18 psi	753 psi	628 psi	-1 psi	753 psi	628 psi
Principal Tension	-67 psi	-83 psi	39 psi	-28 psi	-35 psi	-1 psi	-29 psi	-36 psi

CL Support VIII NA Girder	Construction		Δ	On SPMT		Δ	On SPMT with Torque	
	w/ Initial prestressForces	w/ prestressafter losses		w/ Initial prestressForces	w/ prestressafter losses		w/ Initial prestressForces	w/ prestressafter losses
Shear Stress	315 psi	320 psi	-123 psi	193 psi	197 psi	-7 psi	186 psi	190 psi
Axial Stress	1,407 psi	1,142 psi	-24 psi	1,383 psi	1,118 psi	-2 psi	1,381 psi	1,116 psi
Radius	771 psi	654 psi	-53 psi	718 psi	593 psi	-3 psi	715 psi	589 psi
Principal Tension	-67 psi	-83 psi	41 psi	-26 psi	-34 psi	2 psi	-25 psi	-32 psi

CL Temp Support VIII NA Girder	Construction		Δ	On SPMT		Δ	On SPMT with Torque	
	w/ Initial prestressForces	w/ prestressafter losses		w/ Initial prestressForces	w/ prestressafter losses		w/ Initial prestressForces	w/ prestressafter losses
Shear Stress	243 psi	248 psi	-61 psi	182 psi	186 psi	107 psi	288 psi	293 psi
Axial Stress	1,811 psi	1,459 psi	189 psi	2,000 psi	1,648 psi	287 psi	2,287 psi	1,935 psi
Radius	938 psi	770 psi	79 psi	1,016 psi	845 psi	163 psi	1,179 psi	1,011 psi
Principal Tension	-32 psi	-41 psi	16 psi	-16 psi	-21 psi	-19 psi	-36 psi	-43 psi

CL Temp Support I NA Girder deflected side	Construction		Δ	On SPMT		Δ	On SPMT with Torque	
	w/ Initial prestressForces	w/ prestressafter losses		w/ Initial prestressForces	w/ prestressafter losses		w/ Initial prestressForces	w/ prestressafter losses
Shear Stress	243 psi	248 psi	82 psi	325 psi	329 psi	52 psi	377 psi	381 psi
Axial Stress	1,811 psi	1,459 psi	213 psi	2,024 psi	1,672 psi	-62 psi	1,962 psi	1,610 psi
Radius	938 psi	770 psi	125 psi	1,063 psi	899 psi	-12 psi	1,051 psi	891 psi
Principal Tension	-32 psi	-41 psi	-19 psi	-51 psi	-62 psi	-19 psi	-70 psi	-86 psi

CL Temp Support VIII NA Slab	Construction		Δ	On SPMT		Δ	On SPMT with Torque	
	w/ Initial prestressForces	w/ prestressafter losses		w/ Initial prestressForces	w/ prestressafter losses		w/ Initial prestressForces	w/ prestressafter losses
Shear Stress	psi	psi	psi	psi	psi	psi	psi	psi
Axial Stress	33 psi	-19 psi	-268 psi	-235 psi	-287 psi	287 psi	52 psi	psi
Radius	16 psi	10 psi	101 psi	117 psi	143 psi	-91 psi	26 psi	psi
Principal Tension	psi	-19 psi	-235 psi	-235 psi	-287 psi	235 psi	psi	psi

4.0 Instructions to the Contractors' Specialty Engineer

The general definition often used to describe the Bridge Contractor's Specialty Engineer is defined in Section 1.3 of this manual. The use of movement systems involves two unique engineer groups supporting the Bridge Contractor - these are the Heavy Lifter and the Bridge Specialty Engineer. The Bridge Specialty Engineer will analyze the different support conditions of the bridge and can explore different scenarios for the Bridge Contractor concerning his chosen means and methods of fabrication, transportation, and erection. The Specialty Engineer can also be contracted to provide the engineering for project specific applications of the Contractor's inventory of falsework, cribbing materials, shoring, brace(s), fabrication and casting beds, casting geometry and Owner-defined submittal requirements associated with this type of bridge construction.

The use of movement systems such as Self Propelled Modular Transporters (SPMTs) brings other disciplines of the engineering community into transportation infrastructure design. This area has traditionally been covered by AASHTO Specifications. For this reason the Bridge Specialty Engineer may need some guidance in dealing with large scale lifts while on falsework, stability of a moving frame or impact factors for a bridge in motion. This section addresses the engineering aspects of specialized disciplines that are generally provided by the Bridge Specialty Engineer.

The Contractor's Specialty Engineer and his Heavy Lifter's Engineer communicate information back to the EOR via Shop Drawings, Erection and Falsework Manuals. These submittals document the stress history of the bridge structure. They also fulfill OSHA requirements to have licensed professionals responsible for providing a safe work place.

4.1 Qualifications of the Specialty Engineer

The Specialty Engineer shall be a Professional Engineer and must understand the AASHTO code governing the type bridge being moved and have prepared working drawings for contractors involved in bridge construction. Section 2.1.6 of this manual covers the basic roles, responsibilities and qualifications.

4.2 Criteria

As stated in Section 3 to the EOR, the initial Technical Advisory T5140.24, concerning Bridge Temporary Works, was issued by FHWA on October 29, 1993. The Secretary of the U.S. Department of Transportation was directed by Congress to develop specifications and guidelines for the use in constructing bridge temporary works. The falsework collapse of the Maryland Route 198 Bridge over the Baltimore/Washington Parkway and the fact that no national standard code or specification was available on bridge temporary works precipitated the mandate.

4.2.1 General Guidance and Load Factors for Span Construction on the Temporary Supports

The AASHTO LRFD Bridge Design Specifications clearly address the requirements for the construction loading for traditional span construction up to including the point when the deck is cast on the girders. The guidance below shall be applied without modification to the span before it is moved. Traditional design tools and analysis apply since the span is being cast in the same orientation and supported identically to the in-service condition.

The *AASHTO LRFD Construction* Section 3.1.1 stipulates "Unless otherwise permitted, the design of the temporary works shall be based on the *AASHTO LRFD Bridge Design Specifications* load factors specified in Articles 3.4.1 and 3.4.2, and all applicable load combinations shall be investigated."

The *AASHTO LRFD Bridge Design Specifications* specifies in Articles 3.4.2 Load factors for Construction Loadings. There are two subsequent sections, Section 3.4.2.1 Evaluation at Strength Limit States and Section 3.4.2.2 Evaluation of Deflection at the Service Limit State.

For the Strength Limit State, all appropriate strength combinations, as presented in Table 3.4.1-1, should be investigated. However, when investigating Strength I, III, and V load combination during construction, the load factors for the weight of the structure and appurtenances (DC and DW) should not be less than 1.25. In addition for Strength I, the load factor for construction loads and any associated dynamic affects should not be less than 1.5. Construction loads are loads act on the bridge only during the construction, such as deck finishing machines, falsework, or temporary supports. For Strength III, the load factor for wind should not be less than 1.25 during construction.

Additionally, the *AASHTO LRFD Bridge Design Specifications* specifies in Articles 5.14.1.2.1 the following: "The pre-service conditions of prestressed girders for shipping and erection shall be the responsibility of the contractor." The commentary to the same section states the AASHTO LRFD Bridge Construction Specifications places the responsibility on the Contractor to provide adequate devises and methods for the safe storage, handling, erection, and temporary braces. Many fabricators and contractors still use the allowable stress approach articulated in the AASHTO 1995 *Guide Design Specifications for Bridge Temporary Works* along with Robert Mast Lateral Stability of Long Span Prestressed Concrete Beams (Part 1 & Part 2) approach presented in PCI Journals' dated January 1989 and January 1993 respectively to analyze the pre-service condition of prestressed concrete girders.

The Specialty Engineer is required to evaluate construction stability and deflections based on the Bridge Contractors casting arrangement and the Heavy Lifter proposed support conditions.

4.2.2 As-Designed Information

Within the plans, the EOR shall provide loading assumptions, stresses and deflections for the bridge superstructure. The EOR will calculate the Dead Load of the span based on plan dimensions and quantities of Concrete, Structural Steel and Rebar. Any Stay-in-Place form allowances, build up allowances will be stated on the plans. The Specialty Engineer will validate the Dead loads taking into account any as cast information provided by the contractor. These deflections are based on the Service I load combination. The construction dead loads should be considered as part of the construction transient loads and should be considered as part of the live loads when using the LRFD Design Specification.

4.2.3 Guidance and Load Factors for Analysis of Span during Lifting and Movement of the Span

As an alternate to the LRFD code, The Bridge Specialty Engineer may analyze the bridge structure using the allowable stress approach articulated in the AASHTO 1995 *Guide Design Specifications for Bridge Temporary Works* during construction only. The LRFD code remains the only acceptable design criteria for the in-service bridge. Section 2.2.3 gives the loadings the EOR will assume and if the working drawings call for the span to be completely unloaded before lifting and transportation, the construction loads can be lowered to 0 psf. If Temporary Frames and or external Post-tensioning are on the structure the weight of these items plus 10 pounds per square foot should be used to calculate the stress in the girder.

Section 4.6 of the FHWA 2007 SPMT publication states an impact factor of 15% of the dead load being lifted should be used to account for uneven surfaces. This impact guidance is consistent with the service load range found in Section 3.1.1.a.2. This section of the 1995 publication limits the impact to steel structures but is hereby applied to concrete superstructures for stress computations only. However, for the span under movement by the SPMT where the load is picked gradually using hydraulic systems and then moved at a walking pace, this handling impact factor may be reduced to 5% (as a minimum) in addition to the imposed twist included in the refined analysis. The allowable twist in the Construction Specifications is w/200 and w/300 and shall be modeled in the refined analysis. The Specialty Engineer shall use 15% with a 2-dimensional line girder analysis. Accurate weights are discussed in Section 4.2.2.

4.3 Bridge Structures Erection Stresses

Utilizing the approach found in LRFD 2007 Design Specifications as amended in Chapter 3 of this document.

4.4 Temporary Works Criteria

There are codes and practices that govern the safe implementation of temporary support systems. AASHTO, ASCE and ASME have published codes of practice that will be discussed in this section. AWS is also the generally accepted welding code and is referenced in this section.

For Utah bridge projects the Specialty Engineer may utilize the following codes for the temporary appliances used during the bridge construction. AASHTO 1995: *Guide Design*

Specifications for Bridge Temporary Works, with the AASHTO 1995: *Construction Handbook for Bridge Temporary Works*. All permanent bridge features must be analyzed based on AASHTO LRFD Bridge Code for the final in-service condition.

Many of the design approaches of these non LRFD based documents are based on allowable stress design and care is necessary when converting from the service loadings of the LRFD bridge code. The Specialty Engineer may use loadings from ASCE7-02 and construction loadings from ASCE37-02. The Specialty Engineer may use ASME BTH-1-2005 Design of Below-the-Hook lifting Devices and AWS D14.1 for temporary supports.

In the absence of any other design criteria, the bridge temporary works as a minimum must meet the requirements of AASHTO Guide Design Specifications for Bridge Temporary Works (1995), Article 2.1.5.3 “Factor of Safety” for vertical shoring, jacks and all types of manufactured assemblies and Article 2.3.2 and Table 2.3 “Load Combinations”. The Specialty Engineer for the design of the bridge temporary works must state the basis of the Design Criteria, all assumed loads including wind and impact effects, limits for stability against overturning, combined stresses, deflection and slenderness, on the shop drawings for the Casting bed foundation, erection stability towers, and the forming and temporary false work required in the Contractors Shop Drawings. The Bridge Specialty Engineer shall review the submittal before forwarding it to the EOR. It should be understood that there exists a safety factor for the stated load on SPMTs. For initial design a value of 80% to 85% of the rated capacity of the equipment can be assumed. This value will need to be verified with the manufacture’s cut sheets to insure that the required “Factor of Safety” is adhered to for all equipment, manufactured systems, and components (i.e. Proprietary scaffolds, jacks, etc).

4.5 Checklists

Review the guidance outlined in *Manual on Use of Self-Propelled Modular Transporters to Move Bridges*, Publication No. FHWA-HIF-07-022.

Receive the calculations and details from SPMT Firm for: x y z

4.6 References

UDOT 2008: *Standard Specifications for Road and Bridge Construction*, Utah Department of Transportation, 2008

UDOT 2008: *Structures Design Manual,* Utah Department of Transportation, 2008

FHWA 2007: *Manual on Use of Self-Propelled Modular Transporters to Move Bridges*, Publication No. FHWA-HIF-07-022

AASHTO 2007: *AASHTO LRFD Bridge Design Specifications,* 4th Edition, LRFD, American Association of State Highway and Transportation Officials, Washington, DC.

AASHTO 2004: *AASHTO LRFD Bridge Construction Specifications*, 2nd Edition with Interims through 2007; American Association of State Highway and Transportation Officials, Washington, DC, Section 3, "Temporary Works" and related references herein.

AASHTO 1995: *Guide Design Specifications for Bridge Temporary Works*, GSBTW-1, American Association of State Highway and Transportation Officials, Washington, DC, with particular reference to loads, factors of safety and stability

AASHTO 1995: *Construction Handbook for Bridge Temporary Works*, CHBTW-1, American Association of State Highway and Transportation Officials, Washington, DC.

FHWA 1991: *Synthesis of Falsework, Formwork and Scaffolding for Highway Bridge Structures,* FHWA-RD-91-062, Federal Highway Administration, U.S. Department of Transportation, Washington, DC, November 1991.

FHWA 1993: *Bridge Temporary Works,* TS140.24, Federal Highway Administration, U.S. Department of Transportation, Washington, DC, October 1993.

FHWA 1993: *Guide Standard Specifications for Bridge Temporary Works,* FHWA-RD-93-031, Federal Highway Administration, U.S. Department of Transportation, Washington, DC, November 1993.

FHWA 1993: *Guide Design Specifications for Bridge Temporary Works,* FHWA-RD-93-032, Federal Highway Administration, U.S. Department of Transportation, Washington, DC, November 1993. See also AASHTO GSBTW-1, listed above.

FHWA 1993: *Certification Program for Bridge Temporary Works,* FHWA-RD-93-033, Federal Highway Administration, U.S. Department of Transportation, Washington, DC, November 1993.

FHWA 1993: *Construction Handbook for Bridge Temporary Works,* FHWA-RD-93-034, Federal Highway Administration, U.S. Department of Transportation, Washington, DC, November 1993. See also AASHTO CHBTW-1, listed above.

ANSI / ASME BTH-1-2005 "Design of Below-the-Hook Lifting Devices", American National Standards Institute, American Society of Mechanical Engineers, 2005

AWS D14.1:2005 "Specification for Welding of Industrial and Mill Cranes and Other Material Handling Equipment", 2005

ASCE 7-02: Minimum Design Loads for Buildings and Other Structures", Structural Engineering Institute, American Society of Civil Engineers, 2002

ASCE 37-02: *Design Loads on Structures during Construction*, Structural Engineering Institute, American Society of Civil Engineers, 2002

SC&RA: *Recommended practices for Telescopic Hydraulic Gantry Systems*, with the training Video published by Specialized Carriers & Rigging Association, 2004

5.0 Instructions to the Contractors' Heavy Lifter

The general definition often used to describe the Heavy Lifter Engineer is defined in Section 1.3 of this manual. The use of movement systems involves two unique engineer groups supporting the bridge contractor efforts, the Heavy Lifter Engineer and the Bridge Specialty Engineer. The engineer for the Heavy Lifter will provide the engineering for everything above the ground to below the superstructure span within the movement system.

The Contractor's Bridge Specialty Engineer will integrate the Heavy Lifter's Engineer's submittal into one communication and then the Contractor will submit the information back to the EOR in the form of shop drawings and Manuals for the Erection and Falsework assembles to document the stress history of the bridge structure and to fulfill the OSHA requirements of having licensed professionals responsible for providing a safe work place.

5.1 Qualifications

A professional engineer (Mechanical, Structural or Civil) registered in Utah and qualified to design the SPMT Movement system as defined in this manual.

5.2 Criteria

The initial Technical Advisory T5140.24, concerning Bridge Temporary Works, was issued by FHWA on October 29, 1993. The Secretary of the U.S. Department of Transportation was directed by Congress to develop specifications and guidelines for the use in constructing bridge temporary works. The falsework collapse of the Maryland Route 198 Bridge over the Baltimore/Washington Parkway and the fact that no national standard code or specification was available on bridge temporary works precipitated the mandate.

5.2.1 General Description

The use of movement systems such as Self Propelled Modular Transporters (SPMTs) brings other disciplines of the engineering community into what has been traditionally been covered by AASHTO Specifications. This section addresses the engineering aspects of these specialized disciplines generally provided by the Heavy Lifter.

The Contractor's Bridge Specialty Engineer and his Heavy Lifter's Engineer communicate this information back to the EOR in shop drawing and erection and falsework manuals to document the stress history of the bridge structure and to fulfill the OSHA requirements of having licensed professionals responsible for providing a safe work place. The following instructions apply to both the Bridge Contractor Specialty Engineer and the SPMT Engineer.

5.2.2 Temporary Works Criteria

There are codes and practices that govern the safe implementation of temporary support systems. AASHTO, ASCE and ASME have published codes of practice that will be discussed in this section. AWS is also the generally accepted welding code and is referenced in this section.

For Utah bridge projects the Specialty Engineer (the Bridge Specialty Engineer or SPMT Engineer) may utilize the following codes for the temporary appliances used during the bridge construction. AASHTO 1995: *Guide Design Specifications for Bridge Temporary Works*, with the AASHTO 1995: *Construction Handbook for Bridge Temporary Works*. All permanent bridge features must be analyzed by the EOR or Bridge Specialty Engineer based on AASHTO LRFD Bridge Code for the final in-service condition.

Many of the design approaches of these non LRFD based documents are based on allowable stress design and care is necessary when converting from the service loadings of the LRFD bridge code. The Specialty Engineer may use loadings from ASCE7-02 and construction loadings from ASCE37-02. The Specialty Engineer may use ASME BTH-1-2005 Design of Below-the-Hook lifting Devices and AWS D14.1 for temporary supports.

In the absence of any other criteria, for the design and use of SPMT equipment and all super-works, as a minimum, shall meet the requirements of AASHTO Guide Design Specifications for Bridge Temporary Works (1995), Article 2.1.5.3 “Factor of Safety” for vertical shoring, jacks and all types of manufactured assemblies and Article 2.3.2 and Table 2.3 “Load Combinations”. The signed and sealed submittal shall clearly state the basis of the Design Criteria, all assumed loads including wind and impact effects, limits for stability against overturning, combined stresses, deflection and slenderness, for SPMT systems and super-works Shop Drawings. 1995 AASHTO Section 2.1.5.3 addresses criteria for jacks and will be applied to Hydraulic cylinders, as well. 1995 AASHTO Section 2.5.9.2 addresses the use of hydraulic jacks and the requirement for “The Load imposed by the supports member shall be transferred at the end of the adjustment cycle to a permanent means of support capable of resisting the load with out additional settlement or distortion. This permanent means of support is not to be applied to the internal hydraulic jacks in the SPMT.

Documentation and calculation shall include engineering code references and manufactured products certifications and catalogue cut sheets as part of the erection manual submittal documentation.

Basic Geometry:
Specialty Engineer is responsible for validating the integration of the BSA and the Heavy Lifter’s SPMT Movement System by taking the as cast geometry from the substructure in the field and the graded TP of the SPMT units and checking to assure the minimum and maximum strokes as shown by the SPMT Firm will work. Conversely the SPMT documentation will stipulate the minimum and maximum heights above the ground to the top of the frame. The Specialty Engineer is responsible for validating the camber loss

(distorted shape) and the height of the bearing assemble to be cleared. The bearing assemble may be attached to the bottom of the beam or located on the substructure.

Manufactured equipment such as cranes, forklifts , dollies, rollers, etc. have an operating manual stating the range of application. The SPMT engineer will include such information in his submittal.

During the 2008 Accelerated Bridge Construction- Highways for Life Conference Sponsored by FHWA, U.S. Bridge engineers learned from ing. Jan de Boer of **deboer**dc of two products from a research institute in The Netherlands. The proceeding from the FHWA 2008 workshop states,

> " There are no specific European regulations for bridge-moving techniques. That's why I took the initiative to create two sets of CUR-guidelines, the CUR being a research institute in the Netherlands. CUR 68 covers the design rules and CUR 81 the bridge-moving process.
>
> These rules stipulate essentials for the stability of jacking systems. If design and bridge-moving are based on these guidelines, safety-levels are similar to those with normal static structures. Thus, during jacking and launching, it's also permissible for traffic to continue normally over and under bridges. To test this, CUR 81 has a checklist which makes it very unlikely that human error will compromise the stability of a structure during the jacking operation."

At the time of this writing, these guidelines were in the process of being translated. It is our hope that these guidelines may be incorporated into the standard practices of bridge moving in Utah and across the country. In the interim, the US practice codified in the ASME and ASCE shall be utilized.

5.3 Checklists

- Did the documentation package include the manufacturer data sheets for the equipment?
- Does the Calculations match the assemble drawings for the SPMT system and super-works?
- Are the Factors of Safety stated?
- Do the working drawings of the SPMT super-works clearly showing the HLF blocking, shoring towers, cross frames, strong backs?
- Does the plan adequately illustrate the Picking height and setting height information?
- Are the anticipated jacks operating ranges stated? Are there operating contingencies?

- Are inspection reports and certifications by manufacturers of critical equipment provided?
- Are the max ground pressures stated?
- Are there any areas where special surface treatment is needed? (i.e. steel plating?)
- Has the SPMT Firm shown where temporary foundations are needed for lifting operation (i.e. foundation for climbing jack system)?
- Has the SPMT Firm validated the geometry of the span Travel Path (TP)?
- Does the operational plan explain the following:

  How many pairs of tires maybe removed from service in each SPMT assemble?

  How out of plumb can the SPMT Super-works can be and still be stable?

  Are the auxiliary hydraulic cylinders equipped with emergency check values to prevent sudden loss of pressure?

  Is the hydraulic power system designed in accordance with national standards?

  Are the cylinders equipped with locking rings?
- Do we have the designated personnel listed with backups in the pre-moving planning document?
- Is the engineering included if the SPMT Firm is providing the support structure for a removed span?
- Has the Specialty Engineer provided his validation of the lift points and geometry for setting height computations to the SPMT Firm?
- Is the Draft Stamp removed from all sheets of the submittal?

For additional information, refer to the checklists for submittals in Sections 6.4 and 6.5.

5.4 References

UDOT 2008: *Standard Specifications for Road and Bridge Construction*, Utah Department of Transportation, 2008

UDOT 2008: *Structures Design Manual,* Utah Department of Transportation, 2008

FHWA 2007: *Manual on Use of Self-Propelled Modular Transporters to Move Bridges*, Publication No. FHWA-HIF-07-022

FHWA/AASHTO 2004 International Technology Exchange Program Scan Trip on *Prefabricated Bridge Elements and Systems in Japan and Europe*, Report Number FHWA-PL-05-003, March 2005

AASHTO 1995: *Guide Design Specifications for Bridge Temporary Works*, GSBTW-1, American Association of State Highway and Transportation Officials, Washington, DC, with particular reference to loads, factors of safety and stability

AASHTO 1995: *Construction Handbook for Bridge Temporary Works*, CHBTW-1, American Association of State Highway and Transportation Officials, Washington, DC.

ANSI / ASME BTH-1-2005 "Design of Below-the-Hook Lifting Devices", American National Standards Institute, American Society of Mechanical Engineers, 2005

AWS D14.1:2005 "Specification for Welding of Industrial and Mill Cranes and Other Material Handling Equipment", 2005

ASCE 7-02: Minimum Design Loads for Buildings and Other Structures", Structural Engineering Institute, American Society of Civil Engineers, 2002

ASCE 37-02: *Design Loads on Structures during Construction*, Structural Engineering Institute, American Society of Civil Engineers, 2002

SC&RA: *Recommended practices for Telescopic Hydraulic Gantry Systems*, with the training Video published by Specialized Carriers & Rigging Association, 2004

FHWA Proceedings: *2008 Accelerated Bridge Construction – Highway for Life Conference*, Hyatt Regency Baltimore, Baltimore, Maryland, March 2008

6.0 Bridge Contractor Considerations

UDOT has established this manual of information and this section is only a partial list of additional items and issues for the contractor's consideration while becoming involved with a new specialized industry. While other sections of this document offer engineering instruction this section offers ideas for the contractors use.

6.1 General Information

The Bridge Contractor and his Bridge Specialty Engineer should consider the need for items and details to speed span placement. Many of these decisions will be directly related to the contracts incentive/disincentive and Traffic Control costs. For example, bearing pad alignment and placement has been noted as the pacing item for final bridge lowering. A beam detail could be included in the beam shop drawings for an embedded plate to pre-attach the pad. This assembly would have to have bolts to facilitate the unattachment of the pad after setting. Pads cannot be glued to the girder because that would impede future pad replacement or resetting in the event of excessive displacement.

The Bridge Contractor may wish to budget for some contingency items in the event the temporary supports may settle during span fabrication. The superstructure span can be cast first and then surveyed the "As-Cast" for determining actual beam seat construction that is then made to match. In the event substructure construction is also time sensitive and the pedestal construction cannot be delayed until after casting the superstructure, the use of shim plates may be considered.

Having several small Hydraulic Lifts platforms that will also operate between the SPMT and the pier once the span in positioned above the anticipated pad locations would speed span lowering operations. (Note: Larger telescoping platforms may be too wide.)

Multiple forklifts capable of moving steel plates around also will speed span placement.

Consider an alternate operations plan that could release traffic under the newly placed span without the total removal of the SPMT assembly. This may require temporary barrier placement to protect the work zone.

Depending on the project and owner sensitivity, the Bridge Contractor may wish to require additional contingency items into the Heavy Lifter's system. The least redundant feature is the Hydraulic power unit. Perhaps standby interconnections should be required between power packs that could operate all transporters but at a reduced ground speed. This could allow placement competition or at minimum the safe passage from the roadway to allow the facility to reopen.

6.2 Best Practices

The Specialized Carriers & Rigging Association (SC&RA) published a *Recommended Practices for Telescopic Hydraulic Gantry Systems*, in 2002. Its intended audience is more industrial than heavy Civil but the thought process is very appropriate to movement of bridge spans. Fundamentally, a well planned and carefully executed activity will provide a safe and economically appropriate solution by definition. These below items are activities for consideration by the Bridge Contractor:

1. Develop a clear approach and detailed scope for the SPMT Firm.
2. Identify temporary works options and develop preferred methods.
3. Develop the sequence of activities and develop the BSA layout including crane placement locations.
4. Develop with the Bridge Specialty Engineer and SPMT Engineer an advanced movement schematics and validate site preparation/travel path.

6.3 Checklists at Bid Time

The U.S. Transportation industry will be entering a period of Major Arterial renewal projects. These heavy movement methods will become a key component and these pre-bid considerations serve as a reminder to the Bridge Contactor:

1. Have we received a scope and price from a Specialty engineer? Did the scope match what means and methods of operations the contractor is anticipating?
2. What existing materials does the Bridge Contractor have that maybe used for the temporary works?
   a. What condition are the welds?
   b. Does the Contractor have Mill certifications for any provided steel sections?
   c. Has the SPMT Engineer inspected the Bridge Contractors provided items?
   d. What species and grade timber cribbing is being proposed?
   e. What are the procedures for pointing and patching the Structural Steel Coating System?
3. Who is providing the temporary shoring design and material of the removed span?
4. What are the procedures for pointing and patching the Structural Steel Coating System (paint) and Concrete spalls and cracks?
5. Has someone assembled a list of Special Venders and suppliers to address the bridge movement needs?
6. Did the SPMT Firm include in his price raising or lower the spans?
7. Has the Bridge Contractor included budget for temporary foundations for the cribbing/climbing jacks/lifting towers used by the Heavy Lifter?
8. Is the BSA site preparation labor and material in the earthworks bid? Did it include adequate base material for the Travel Path (TP) to the bridge site?
9. Is there budget for the Traffic control during span placement? During girder delivery? During periods of intense material delivery like Concrete for deck placement?

6.4 Checklists for Submittals

6.4.1 General

The following are for guidance purposes when preparing Shop Drawings, Geometry Control Procedures, SPMT Movement System Operations Manuals, and other material for submittal for review and approval. These lists are not exhaustive. Other matters shall be addressed by the Contractor in his submittals according to the nature and needs of the project.

Ensure that all materials, details and procedures are as specified herein, as noted on the Plans, [Utah DOT Standard Specs, UDOT Standards ("Go-Bys")] or as directed by the owner.

6.4.2 Traffic Control Plans (TCPs)

Show proposed traffic operations plans for:

1. Movement of SPMT system from Bridge Staging Area (BSA), along the TP and for setting span in place at the Bridge Site.
2. Temporary closing of local highways.
3. Rolling road-blocks.
4. Provisions to be made in case of breakdown or emergency.
5. Points of contact - persons and authorities.
6. Detailed schedule of activities.

6.4.3 Bridge Staging Area (BSA)

Details of BSA, location, general layout, surface grading, surfacing material, drainage, environmental protection, material storage areas, rebar fabrication areas, concrete mixing plant, concrete delivery methods, shelters, steam curing plant, SPMT TP(s), accesses, fences, gates, barriers, offices, workshops, and the like.

Foundations and details for construction of temporary bents or abutment type seats to support span under construction - include piling, spread footings or other foundation preparation.

Preparation of TP (see below).

Proposed locations of benchmarks or other reference locations for geometry control and survey purposes.

6.4.4 Travel Path (TP)

Show TP(s), locations, clearances, details of construction, intended access under completed superstructure at lift locations. Provide information and details which included but are not limited to:

1. The layout and details of the staging area for the prefabrication of the superstructure span(s) or for the demolition of spans removed from an existing structure.

2. Locations of temporary structural supports and means of setting of prefabricated steel or precast prestressed concrete girders to elevation on prepared temporary supports in the BSA.
3. Disposition of Self Propelled Modular Transporters (SPMTs), including all loads and reactions applied to the TP, including those applied to any structures along that TP.
4. The means of mitigating unacceptably high or concentrated loads, if necessary by the use of spreader plates or other means.
5. Procedures for each movement of each prefabricated superstructure together with supporting calculations for actual and allowable bearing pressures along the TP carried out by the *Contractor's Geotechnical Engineer.*

6.4.5 Temporary Support Structures

Show proposed location and details of temporary supports for superstructure. Include bents or ground beams and temporary piling. Take responsibility for the design and engineering of temporary support structures.

6.4.6 Permanent Superstructure

Show proposed details for prefabrication of the permanent superstructure, including but not limited to:

1. Dimensional, structural or similar physical changes to the superstructure itself and calculations for the verification of stress levels within or the strength capacity of the superstructure necessitated by the use of the Contractors elected SPMT construction method. (This applies to the permanent superstructure itself, not the SPMT system, its components or related geotechnical considerations). This includes, but is not necessarily limited to those things arising from: changes of locations of temporary and/or permanent support conditions, changes to cross-section component sizes and/or connectivity (shear studs or shear reinforcement), relocation of construction joints (in any plane), sequence and installation of pre-stressing forces (by pre- or post-tensioning), distortion (twist) or differences in deflection or camber from unintentional support settlement or differences in anticipated elevations, unexpected changes of conditions during lifting, transportation and setting of the superstructure and the like.
2. Details for forms for the deck and any diaphragms or similar members to be cast along with the superstructure.
3. Where minor variations are made to superstructure geometry, dimensions shown in the Contract Plans, show appropriate changes to reinforcing clearly showing the size, spacing and location, including any special reinforcement required but not shown on the Contract Plans, with a clear and concise cross-reference to the appropriate Contract Plans to which the variations apply. Variations to these dimensioning will change the weight the Heavy Lifter will is transporting. Concrete mix will also have an influence.
4. Details of anticipated camber of prefabricated girders (steel or concrete) prior to and after casting a deck slab, along with any appropriate adjustments in the setting of deck forms, as necessary.

5. For concrete pours, show locations of proposed construction joints (in any location and plane) on and proposed concrete pouring sequence
6. For monolithic cross-sections, such as box girders or voided slabs, show proposed sequence of discharge of concrete into bottom slab, webs and top slab so as to maintain fresh areas of concrete for consolidation and working a new charge into a previously placed area to avoid the formation of cold joints. Also, show locations of proposed horizontal construction joints in webs, diaphragms and the like.
7. For deck slabs, show on shop drawings, location and proposed sequence of discharge into slab so as to maintain fresh areas of concrete for consolidation and working a new charge into a previously placed area to avoid the formation of cold joints.
8. Details of adjustments to the elevations or positions of abutment and pier bearings as necessary to accommodate the prefabricated superstructure.
9. For purposes of measurement and payment, the volume of concrete, weight of structural steel girders, size, type and weight of prestressed concrete girders, weight of reinforcement, type size and number of shear studs, weight of post-tensioning in each prefabricated superstructure as appropriate and as necessary.
10. In the event of cracking or damage, proposals for the injection and sealing of cracks, repair of damage and verification of the repaired superstructure all supported by calculations, as necessary, prepared by the Contractor's Specialty engineer.
11. Include embedded items such as post-tensioning hardware, scuppers, manholes, anchor bolts or fixtures for bearings, barriers or light-poles, signs, utilities, and similar appurtenances. Make sure all such items are in their correct locations and elevations in accordance with tolerances required by the owner's requirements.
12. Details for protection of epoxy-coated barrier reinforcing bars, couplers and splices at designated construction joints. The lifting and movement will cause higher stress in the barriers/railings. Postponing the casting of a portion or all the railing maybe required unless temporary measures such as embedded couplers, temporary post tensioning. Pre-staged material placed on the superstructure deck at the BSA must be accounted for by the Bridge Specialty Engineer and the Heavy Lifter.

6.4.7 Geometry Control (Deflection and Twist) Checklist:

The following list is an example for guidance purposes only. The Contractor's Submittal is to contain actual details of the SPMT Geometry Control System proposed. This maybe in the form of shop drawings or a manual and should include but is not necessarily limited to:

1. Measuring equipment, procedures and locations of geometry control reference points on the superstructure, in the staging area and at the bridge site.
2. The location and values of permanent benchmarks and reference points in the staging area and at the bridge site.
3. Deflection profiles of prefabricated steel or concrete girders under their own self weight, under the additional weight of the cast-in-place concrete and forms and long-term deflections, under the effects of creep and shrinkage, along with

appropriate cambers proposed for construction at the staging area and anticipated long-term behavior after setting at the site.

4. A geometry control procedure for monitoring the distortion (twist) and relative deflections at support locations, of the as-constructed concrete surface of each span (and / or multiple continuous spans) before, during transportation and after setting the superstructure span (or spans) in position permanent position on site. (For example, the distortion (twist) of the deck surface of a single span can be ascertained by monitoring relative elevations of survey bolts set in the concrete at each of its corners.)
5. During casting operations, establish and maintain a record of key vertical elevations along the main longitudinal elements (i.e. centerline of beams, box girders, or webs, as appropriate) as a minimum, at the temporary supports, mid-span and quarter-points of each span. Maintain record in good condition so that it may be used for reference during transportation and erection.
6. Establish lateral and longitudinal location reference points on the prefabricated superstructure that correspond to, or can be referenced to appropriate lateral and longitudinal location reference points at the erection site.
7. Use experienced personnel to operate survey instruments and supervise the casting operation. Obtain approval of Engineer of the experience and qualifications of supervisory and survey instrument operating personnel, particularly with regard to observational precision required.

6.4.8 SPMT Movement System and Operations Checklist:

The following list is an example for guidance purposes only. The Contractor's Submittal is to contain actual details of the SPMT System proposed for use:

1. Details of the number of SPMT units proposed to be connected laterally and/or longitudinally for each support location underneath the bridge superstructure to be transported.
2. Details of the ***platform super-works*** necessary to support the superstructure above the platforms of the SPMT units. This includes but is not limited to additional hydraulic jacks, blocking, columns or towers, stabilizing devices, strong-backs and cross-frames and ties, shipping-containers, grillages, cribbing, shims and any other incidental components needed to support the superstructure atop the SPMT platforms.
3. Details and sequence of procedures for positioning SPMT units underneath a superstructure, and actively engaging the load. Include steps for incremental lifting and insertion and removal of *super-works* or partial *super-works* components, as necessary.
4. Allowable limits for loss of support by any pair of wheels or axle line along with operations, "fail-safe methods" or procedures to facilitate completion of operation with minimal disruption or delay to traffic - by, for example, cross-linking of hydraulic controls at a reduced travel speed.
5. Checking (QC/QA) procedures prior to a transportation operation in order to ensure its completion.
6. Contingency plans in the event of a major breakdown or equipment failure - such as for example, means by which SPMTs can be rendered sufficiently safe to

enable traffic to pass beneath until the source of the problem is found and corrected.

7. Operational details for the control of the movement, lifting, transportation, setting down of the SPMT System may be provided in an "Operations Manual" which may also include a system of check-off's for the Operators and for safety purposes.

6.4.9 Other Miscellaneous Information

On Shop Drawings or other details consider and show as necessary, details for cast-in-place closure joints, expansion joint seats, forming and construction of cast in place details, installation of expansion joint devices, barriers, medians and other miscellaneous appurtenances.

6.5 Example Pre-operations Checklist for Jobsite SPMT Operations Manual

Complex bridge construction always requires the Contractor submit an "Erection Manual" to include the step-by-step sequence of operations for his "Erection Gantry" or other equipment. The following checklist is an example for guidance purposes only of the type of information to incorporate in a "story-board" format on the Shop Drawings or Bridge Movement Operation Manual. The Contractor's Submittal is to contain actual details for the proposed SPMT System and operations.

6.5.1 Initial Lift of Span at BSA using SPMT System

Clear area beneath prefabricated superstructure of debris and unnecessary obstacles such as nails, bolts, screws, etc.

Check ground and TP for damage or unexpected defects since prepared.

Check clear height and width available ready to receive SPMT System.

Check actual overall height and width of SPMT System prior to insertion.

Check functional capabilities of SPMT System.

Install crossed-diagonal twist monitoring detection lines at predetermined locations and elevations just above surface of deck slab and set to allowable twist-distortion limit. Use non-corroding electrical sensors connected to lights or horn system to detect when twist-distortion limit is likely to be exceeded.

Install plumb-line device to establish vertical direction at middle of each end of deck and at mid-span of each edge beam. Scribe a circle on deck centered on each plumb-line, outside of which the plumb-line should not pass during lifting and transportation. Else, use non-corroding electrical sensors connected to lights or horn system to detect when any plumb-line reaches its allowable limit. Use plumb-lines at least 4 feet long. Suspend each plumb-bob in a suitable liquid in a container to dampen wind disturbance.
Drive SPMT under span and locate at designated lifting positions.

Just before lifting, record elevations at designated locations at each end of span, mid-span and lift points on each of the two edge beams and check twist detection lines are set.

Engage SPMT lifting system and slowly take load of superstructure span.

Watch for relatively even lift-off at all bearings.

Check engaged weight against anticipated weight given on Shop Drawings.

Record new elevations at ends, mid-span and lift points to determine deflections relative to those recorded just before lifting.

Record twist distortion, if any, indicated by detection lines.

If during lifting, twist distortion and/or deflection appears likely to exceed allowable limit, immediately stop lifting and check SPMT system for defective functioning or loss of support.

Likewise, if any plumb-line appears likely to exceed its allowable limit, immediately stop lifting and check SPMT system for defective functioning or loss of support.

If necessary, return span to temporary supports in order to examine and repair and defects or leaks in SPMT System.

When span has been successfully lifted and all monitoring devices are within tolerance limits, transport may proceed.

Verify the bridge is at the setting height.

6.5.2 Transportation

Walk the TP and verify clear of debris and obstructions.

Wait for TCP deployment.

With all SPMT Systems functioning properly and with all tolerance monitoring devices within limits, begin move to Bridge Site.

If during transport, twist distortion appears likely to exceed allowable limit, immediately stop and check SPMT system for defective functioning or loss of support.

Likewise, if any plumb-line appears likely to exceed its allowable limit, immediately stop transport and check SPMT system for defective functioning or loss of support.

Follow established procedures on Approved Shop Drawings or Operational Manual to place superstructure and entire SPMT System in safe mode while it is examined and repaired, as necessary.

When SPMT System has been successfully returned to fully functioning mode and all monitoring devices are within tolerance limits, transport may continue.

6.5.3 Setting Bridge Span in Place

Check clearances at installation site - vertically, horizontally and skew-wise - to ensure span can properly enter intended permanent in-place location.

Check that all bearings are at planned elevations and match the underside elevations, slope and profile of the already completed span.

Have all materials and equipment on hand at site to accommodate (previously approved) installation on bridge bearings.

Bring span into close proximity in elevation and location.

Prior to final setting down, take a set of elevation observations on deck “before setting.” These measurements should not add time and can be surveyed while Bridge Contractor aligns bearing. These twist measurements are for transportation.

Set span down on bearings.

Take final set of elevation observations after setting span in permanent, final place to verify that tolerances (elevations, locations, twist and deflection) are within anticipated and allowable limits shown in the specifications for permanent elevations. (Note these are not the twist calculations used for transportation of w/200 or 3” at the bridge supports.)

Notify owner of any errors or out of tolerance situation. Propose and seek approval for rectification - or rectify in accordance with previously approved concepts involving shim plates. This may involve the re-lifting and resetting of the span.

Report final setting operations on project records.

6.5.4 References

UDOT 2008: *Standard Specifications for Road and Bridge Construction*, Utah Department of Transportation, 2008

SC&RA: *Recommended practices for Telescopic Hydraulic Gantry Systems*, with the training Video published by Specialized Carriers & Rigging Association, 2004

ASBI 2007: *Design Fundamentals and Geometry Control of Segmental Bridges,* American Segmental Bridge Institute, Annual Seminar, Seattle, 2007

ASBI 2005: *Construction Practices Handbook for Segmental Concrete Bridges* American Segmental Bridge Institute, 2005

7.0 Bridge Inspection Unit Information

7.1 General

This section addresses key information required and key activities to be undertaken by field teams responsible for the overall inspection of the project - including work at the Bridge Staging Area (BSA), along the Travel Path (TP) and at the bridge site - for spans built using SPMT methods.

Activities that are already familiar to site teams experienced in ordinary bridge construction are not addressed. Ordinary bridge construction refers to such work as foundation and substructure construction, setting bearings, erecting beams of steel or prestressed concrete, installing formwork, tying reinforcement, placing, finishing and curing concrete, installing traffic barriers and other familiar work. The purpose of this section is to address matters that are special to construction work using SPMT movement systems.

7.2 Camber Calculations and Field Measurement

At the BSA, it is the intent that the elevations of the temporary bridge bearings relative to one another match exactly the same relative elevations of the bearings at the bridge site itself. This applies to both construction of a new span or the removal and setting down of an existing span for demolition or temporary storage for refurbishment, according to the overall job purpose. In order to provide working clearance for an SPMT system, the temporary bearings should be about 5 feet above the elevation of the TP.

For the construction of a new span at the BSA, certain camber information is needed for monitoring purposes. Who provides and who approves this information depends upon the type of construction contract.

(DBB and CMGC) For Design-Bid-Build contracts, this information is provided (by the EOR) on the Contract Plans, verified by the Contractor's Bridge Specialty Engineer on Shop Drawings according to the properties of materials and the means and methods selected by the Contractor and approved by the Shop Drawing Review process.

(DB) For Design-Build projects, this information is provided by the Contractor's Bridge Specialty Engineer on his Shop Drawings Plans and approved by the EOR and the Owner. If the Bridge Contractor has the EOR provide these services, then these critical acceptance values may need to be verified by an independent engineer, for example the CEI. Other UDOT practices will need to be consulted.

Key information required for SPMT construction is summarized as follows:

1. The cambered profile of the beams, whether steel or prestressed concrete. Both the anticipated camber from calculations and the actual camber from fabrication

are required. It may be necessary to make adjustments to the bearing elevations at the bridge site and/or to the depth of build-up cast over the beams in order to match as close as possible the desired final profile grade.

2. The deflected profile of the beams under the load of the formwork and wet concrete when placed - to give the anticipated "As-Cast" profile. The actual deflection of the span might differ from this. For normal bridge construction on site, it is not necessary to measure the actual deflection. Likewise, at this stage for SPMT construction, it is not essential to measure this deflection either.
3. If post-tensioning is to be applied to the composite slab-beam section, then the anticipated, calculated, upward deflection is required. The magnitude of the maximum anticipated upward deflection should be taken into account when determining or checking final bridge bearing elevations (a) above. For normal bridge construction, it is not necessary to measure the actual upward deflection. Likewise, at this stage for SPMT construction, it is not essential to measure this deflection. However, if it is measured, it enables a direct comparison between theory and actuality which can be useful for verifying engineering assumptions, for subsequent checks or for making adjustments to bridge bearing elevations if necessary.
4. The deflection of the composite span under the weight of any superimposed dead loads such as traffic barriers, utilities, sidewalks and any other appurtenances. Again this should be taken into account for setting final bridge bearing elevations in Step 1 above.
5. The deflected profile of the completed span when it is picked up by the SPMT movement system. In particular, relative to points at the center of the span, the change in deflection of each end of the span from just before to just after being picked up by the SPMT. This change in deflection offers a relatively simple approach to monitor and control deflections under lift and transport - which, in turn, is used to limit undue stress or damage. =
6. The maximum twist the span can tolerate or is otherwise deemed an acceptable limit for control purposes during movement operations. For simplicity and ease of application on site, this twist limit should be given as the maximum change in elevation (in feet or inches) that one corner of the span may experience relative to the plane defined by the other three corners. For this purpose, the corners are defined in two ways - first, by the centerlines of the edge beams over the locations of the permanent bearings - secondly, by the centerlines of the edge beams over the centers of the SPMT support points. It is suggested that the first (at Permanent bearings) be limited to W/200 (or 3inches.) and the second (at Centerline of SPMT temporary supports) to W/300 (or 2ins.) whichever is the least - where "W" = the minimum lateral spacing between the two edge beams. This simplified approach is limited to decks with approximately parallel bents and approximately parallel girders.

The above information (1 through 6) should be provided on the Bridge Plans - by the responsible party according to the type of contract - DBB, DB or CMGC. Methods and procedures for using this information during construction, moving and placing the span in place should be addressed on Shop Drawings or in other appropriate documents (such as record keeping charts, construction manuals) by the Bridge Contractor. Such procedures should be a part of the overall Quality Control (QC) system for the project - for which the primary responsibility for coordination and operation lies with the Prime Contractor.

The party responsible for Construction Engineering and Inspection (CEI) will incorporate appropriate, parallel checks within their Quality Assurance (QA) procedures.

All QA and QC checks, field observations, Shop Drawings will become part of the project records ("As-Built" information) and kept as appropriate for permanent record keeping purposes as required by the Owner.

7.3 Deflection and Twist

After a span has been completed, deviations from "As-Cast" or "As Completed" bridge profile elevations occur when the span is lifted from its original support system and load transferred to the support of the SPMT movement system. The deviations arise from two sources. The first source is deflection due to a change in support conditions from the temporary bearings under each end of the span to the SPMT supports approximately 15 feet inboard from the ends. The second source is from twist. Twist is a direct result of not maintaining exactly the same relative slope relationships over the bridge bearings and diaphragms at each end of the span. The deflection and twist induce stress levels that may or may not be acceptable and which, if not kept to a minimum, might cause damage to the new span.

As a span is built, it undergoes a series of changes in deflection profile as a result of loads applied first to the beams alone and then to the composite section. (Refer also to Appendix B.) Then the span experiences a significant change in deflection profile when the supports are moved inboard from the ends as it is picked up by the SPMT movement system. This induces negative flexure and top fiber tension over the SPMT supports. This top tension is experienced by the deck slab, by the beam acting compositely and by any railing cast above the slab. Without careful control and mitigation - such as deliberate introduction of joints in railings or provision of sufficient mild steel reinforcement in a slab, cracks may be induced. Monitoring of the change in the deflection profile before and after lifting provides a good indication of the likelihood of exceeding tolerable limits for such tensile stress. If the beams are of prestressed concrete, it is likely that the top fibers of the beams in these end regions already experience some level of tensile stress from eccentric prestressing effects. So there are good reasons to maintain control over top fiber tension stresses during SPMT operations.

Twist is a structural warping of the span due to uneven support along each end that allows one corner to deflect from the plane of the span or relative to the plane defined by the other three corners. Such twist induces stress whose magnitude increases with increasing twist or increasing deflection of that corner. Such twist occurs when the relative slope relationships change as load is transferred from the as-cast support system to the SPMT. It can also occur at any time during transport from the casting location to the final location as a consequence of uneven support or settlement along the TP. It can also occur when the span is transferred from the SPMT to the final position in the bridge. Ideally, a span should be lifted from the as-cast support system, transported and placed in its final position with little or no twist to maintain a near stress-free state.

Twist calculations are performed by computing the difference in cross slopes at both ends of a span from its initial as-cast position to its transport/final position. The difference in slope at each end of the span determines the twist value.

Twist corrections are made by computing the slope at one end of a span and making adjustments to the other end of the span that will result in the same (original or as-cast) slope. Twist correction adjustments are made to only one end of the span.

Sample forms for observations and calculations of deflections and twists are provided at the end of this section.

7.4 Span Deflection and Twist - Survey Monitoring Procedures

The following procedures, or ones that are very similar to them, are recommended for monitoring of spans during movement operations. The "Steps" listed are intended mainly as a guide and should not be considered mandatory. Variations upon these procedures may be proposed by the Contractor for review and approval by the Owner. The goal is to move the span in a carefully controlled manner that maintains stresses within allowable limits at all times and results in no permanent damage or cracking.

1. Establish benchmark elevations at stable locations independent of the span being monitored. Locate benchmarks where the level rod can be seen from all benchmarks after the span has been completed.
2. Place survey control elevation rivets or bolts at prescribed locations immediately after finishing of the deck slab concrete. It is recommended that these locations at a minimum be over each edge girder at mid-span, over each permanent bearing and over the centers of the proposed SPMT lifting supports. This makes a total of at least 10 prescribed reference locations. Use elevation rivets or bolts of stainless steel epoxied into the deck, inserted so the top is close to but slightly below the finished concrete surface. Each rivet or bolt should have a punch mark to be used as a repeatable reference location during span deflection and twist monitoring.
3. Install a point (ex: Plumb Bob tip) in the bottom plate of a level rod that can be inserted in the repeatable reference punch mark location in the elevation rivets or bolts used for deflection and twist monitoring.
4. Record elevations for all ten reference points on the Span Deflection and Twist Monitoring form and calculate the As-Cast Shape at both the Bridge Bearing reference points and the SPMT Lift Support reference points. At this stage, the recorded elevations and shapes are referred to as As-Cast Survey elevations and As-Cast Shapes. (This information is recorded on the "As-Cast" form - see example at end of this section).
5. If the superstructure is longitudinally post-tensioned after the deck slab has been completed, it is recommended that another set of elevations be recorded just

before and just after any longitudinal post-tensioning forces are applied to the composite section beams. Retain these for record purposes. If made, these are referred to as post-tensioned elevations and shapes. (This information is also recorded on the “As-Cast” form - see example at end of this section). This geometry should be verified against the final deck elevations. In a multiple span structure, pier elevations cannot easily be adjusted.

6. Any barriers or other appurtenances might be added before the span is lifted and taken to the bridge site. It is not considered necessary to monitor changes in deflections from the application of such relatively minor loads. However, it is important to take a set of readings just before lifting the span.
7. Just before the span is to be lifted by the SPMT movement system, record elevations for all (ten) reference points. Record observations of the span deflection and twist on the “Before Lift - After Lift” form - see example at end of this section) Calculate the before lift shapes (referred to as “Shape 1” on the example form) at both the Bridge Bearing reference points and the SPMT Lift Support reference points. Make a note of the elevation profile along each beam. These are the before lift elevations and are referred to as “Span Shape Field Survey” on the example “Before Lift - After Lift” record form.
8. Determine the deflected profile along each edge beam at this stage by calculating the difference in elevation between each reference over the bridge bearings and SPMT supports from the elevation at mid-span on that edge beam. This represents the deflected profile along each edge beam at the before-lift stage (Step 7).
9. Just after the span has been lifted off its temporary bearings and, very importantly, before it is moved, observe and again record elevations for all ten reference points on the “Before Lift - After Lift” record form. Calculate the shapes (referred to as “Shape 2” on the example form) at this stage (Step 9) at both the Bridge Bearing reference points and the SPMT Lift Support reference points. These are referred to as the “After Lift Shapes”. The difference between the before and after lift shapes gives the amount of structural “Twist”, if any, induced by the lifting operation (e.g. Shapes from Step 9 minus Shapes from Step 7). If the calculated twist exceeds the allowable twist, seek guidance from the Owner (Step 13 below). The Owner may involve the EOR or an independent engineer.
10. Just after lifting, using the elevations recorded along each edge beam, determine the deflected profile along each edge beam at this stage by calculating the difference in elevation between each reference over the bridge bearings and SPMT supports from the elevation at mid-span on that edge beam. This represents the deflected profile along each edge beam at the after-lift stage (Step 9).
11. Calculate the change in the deflected profile from just before to just after lifting by deducting the calculated deflected profile of Step 7 from that of Step 9. This is the deflection change due to the lift and is referred to as the “Observed deflection change relative to mid-span” on the “Before Lift - After Lift” example form). Observed values should compare reasonably well to values calculated in advance or determined from deflection theory.
12. It is important to monitor changes in Span Deflections and Twist at different phases as the span is lifted and transported since this is where the span is likely to

deflect and twist (distort) due to variation in support at the SPMT lift points. If excessive deflection or twist begins to develop in the span, consult the Owner before making the necessary adjustments at the SPMT supports to keep the span within required tolerances. (Record these observations on the "Before Lift - In Transit" example form at the end of this section)

13. If Span Twist adjustment is needed, consult the Owner before making the adjustments. Adjust the Span Twist as near as possible to .000 while allowing for changes due to variations in the TP of the SPMT. Be aware that the TP for the SPMT should not have a variation in cross-fall more than the allowable twist tolerance in a distance shorter than the length of the SPMT movement system.
14. Monitor the span deflection and twist during transport to assure the required tolerances are not exceeded. Unless automated twist monitoring procedures are set in place (refer to Appendix B for a possible method), this may require the transporting operation be stopped while the survey is recorded and calculations are made to show the twist remains within the required tolerances. (Record these observations on the "Before Lift - In Transit" example form at the end of this section).
15. For carrying out intermediate checks during transportation, any elevation bolt can be used as a temporary benchmark for a survey of relative rivet or bolt elevations. Alternatively, a direct elevation rod (ex: Lenker Direct Elevation Rod) can be used and set to a specific elevation on a survey bolt. The remaining survey bolts can be read as elevations directly from the rod and the Span Twist and Deflected profiles can be calculated in the same manner as above.
16. Just before setting the span in its final position, and before releasing any load from the SPMT movement system, record elevations for all ten reference points on the "Before Lift - Prior to Setting" observation record form - see example form at the end of this section. Calculate the Shape at both the Bridge Bearing reference points and the SPMT Lift Support reference points. Compare this Shape with previously calculated Shape just after lifting from the BSA (Step 9) and determine if the Twist (i.e. Shape from Step 16 minus Shape from Step 9) is acceptable or if an adjustment is needed. If Span Twist adjustment is needed, consult the Owner before making any. If necessary, adjust the Span Twist as near as possible to .000 to make the span parallel to the bearings.
17. Lower the span into position in a controlled manner onto the permanent bridge bearings and avoid placing twist into the span.
18. Record elevations for all ten reference points on the "Before Lift - After Setting" observation record form - see example at the end of this section. Calculate the Shape at this stage (Step 18) using formulae applied at both the Permanent Bearing reference points and the SPMT Lift Support points just "After Setting" the span in its final position. This is referred to as the span shape at setting. Calculate the amount of Permanent Twist induced in this final condition from the difference between the shapes at this stage and those just before the span was lifted. (i.e. Shapes at Step 18 minus Shapes at Step 7) The amount of Permanent Twist should not exceed the allowable. If it does, seek guidance from the Owner for appropriate means of correction. (i.e. such as shimming bearings or other measures).

19. Conditions for a span should never exceed the allowable tolerances for Lift Deflection Change and Twist from the time it is lifted from its bearings at the casting location until it is placed in its final position at the erection site.
20. Keep above records for QA/QC and permanent "As-Built" information.

The above procedures are incorporated in the following sample record and calculation spreadsheets provided below for guidance purposes. Formulae for calculating deflection and twist are provided in Section 9.0. Alternative procedures, observation techniques and calculations may be adopted with the approval of the Owner.

7.5 References

The above procedures were derived and developed with reference to similar procedures in common use for the construction of segmental bridges and for the example illustrated in Appendix B. Refer to Appendix B and for additional information, refer to:

ASBI 2007: *Design Fundamentals and Geometry Control of Segmental Bridges,* American Segmental Bridge Institute, Annual Seminar, Seattle, 2007

ASBI 2005: *Construction Practices Handbook for Segmental Concrete Bridges,* American Segmental Bridge Institute, 2005

8.0 Appendix A- Deflection and Twist Monitoring

Whether constructing a new bridge superstructure span or moving an already completed or existing (old) bridge span, it is necessary to control operations in such a manner that causes no undue distress or damage, such as cracking. When the existing (old) Span is going to be demolished and not reused in part or in whole the monitoring maybe waved by the owner if the Contractor's Specialty Engineer has demonstrated the structure does not need temporary strengthening and is not violating the AASHTO Guide Design Specifications for Bridge Temporary Works. The process of establishing and monitoring a workable "Survey Geometry Control" system is best illustrated for the case of a new span. The procedures can be adapted as necessary for moving an existing span and placing it on a new or a rehabilitated substructure. As an alternate method, the project staff may elect to monitor bridge condition using sensors and data collection system. In this case, the monitoring system must be approved by UDOT and the design engineer.

At the Bridge Staging Area (BSA), steel or concrete beams are first placed on temporary supports, as shown in Figure 8.1, Step 1. Beams are usually cambered upward to allow for the anticipated dead load deflection from the weight of the deck slab and any formwork directly supported by the beams themselves. This weight causes a downward deflection which reduces, but does not necessarily eliminate, the camber, as shown in Figure 8.1, Step 2. The amount of deflection can be calculated using deflection formulae from beam theory.

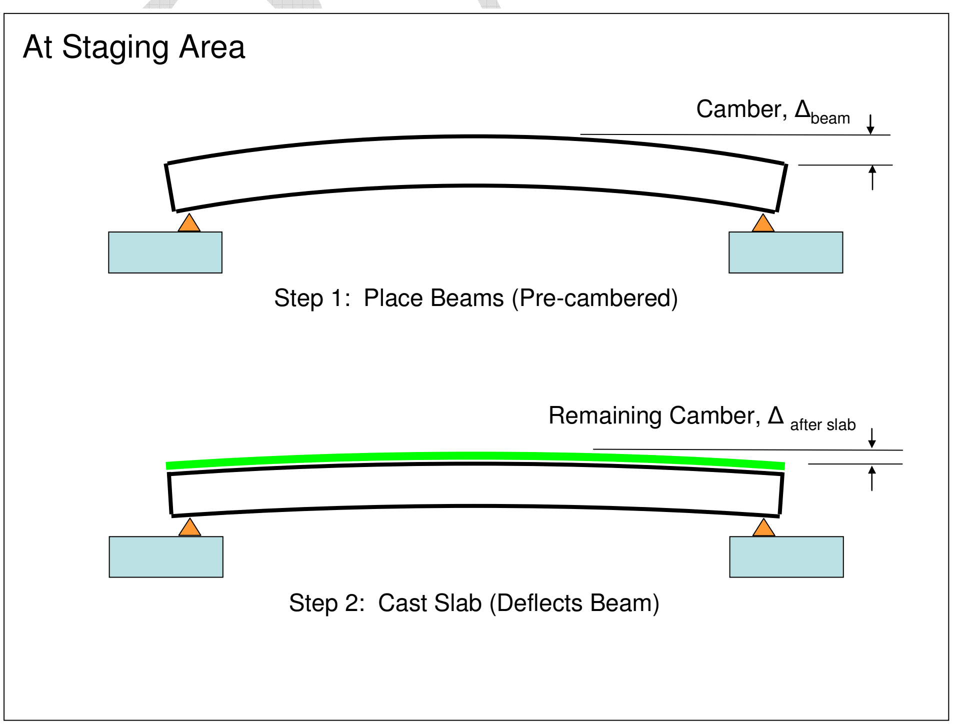


Figure 8.1 Set beams and cast slab

The tracking of the structural behavior of the deck is easily monitored by checking elevations at predetermined locations on the deck slab at each stage of interest as construction proceeds. To make sure that elevations are always recorded at the same locations, it is recommended that small stainless steel rivets or bolts be cast into the top of the deck slab surface, as in Figure 8.2, Step 3. Since in reality, we are interested only in the changes in elevations from one stage to another, it is preferable, but not essential, that the rivets be close to or at the finished level of the deck slab at each location. Their initial values are determined by reference to benchmarks previously established in this case, in the BSA. The contractor will be monitoring the temporary seats for settlement and therefore his same remote bench mark could serve as an initial reference.

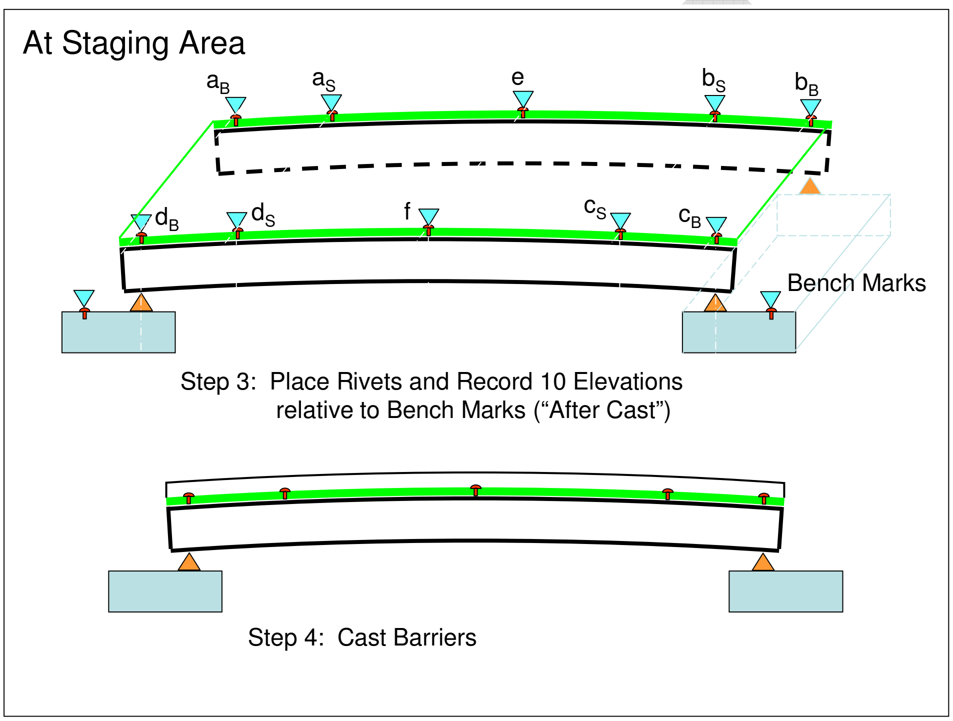


Figure 8.2 Locate and record elevations, cast barriers

During the time from the initial setting of the elevation rivets to casting any barriers for example, individual rivet elevations might change a little - perhaps due to creep or daily temperature changes. Such changes of academic interest and would not normally be recorded. A more discernable difference in elevation may be observed when the dead load of items such as barriers is applied to the now composite beam-slab section.

The most significant change in deflection - and the possibly attendant but inadvertent introduction of twist perhaps from uneven supports - occurs at the time just before and just after lifting, as in Figure 8.3, Steps 5 and 6.

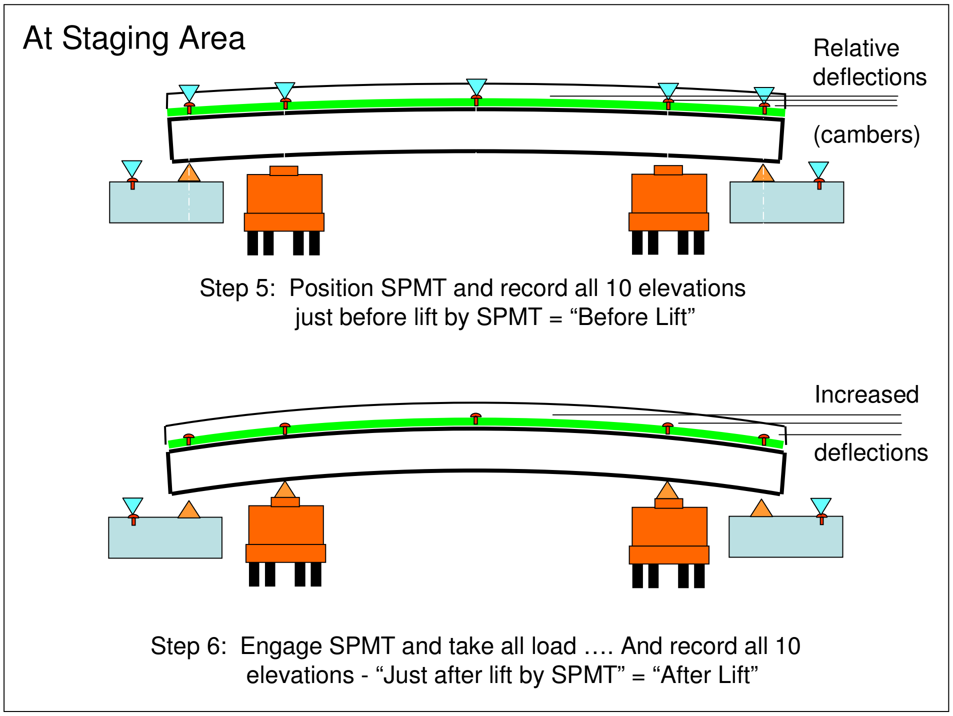


Figure 8.3 Record elevations before and after lift

Step 5, represents the situation of the span on the temporary abutment seats just before lifting. This is the most important reading for evaluating the movement operations. Step 6 represents the situation just after transfer to the SPMT supports. Since these supports are at different locations (i.e. inboard of the span from the permanent bearings) there is a change in static scheme with an accompanying change in calculable and measurable deflections. The differences in the set of elevations observed just before and just after lifting gives the change in deflection - as observed on the ten rivets in the slab and should be close to the values reported by the Bridge Specialty Engineer and agreed to by the EOR.

Figure 8.4 illustrates the two key concerns of the owner at this point. These are: Question 1 - is there a twist and is it within tolerable limits? And Question 2 - is the observed change in deflection profile also as expected or within tolerable limits?

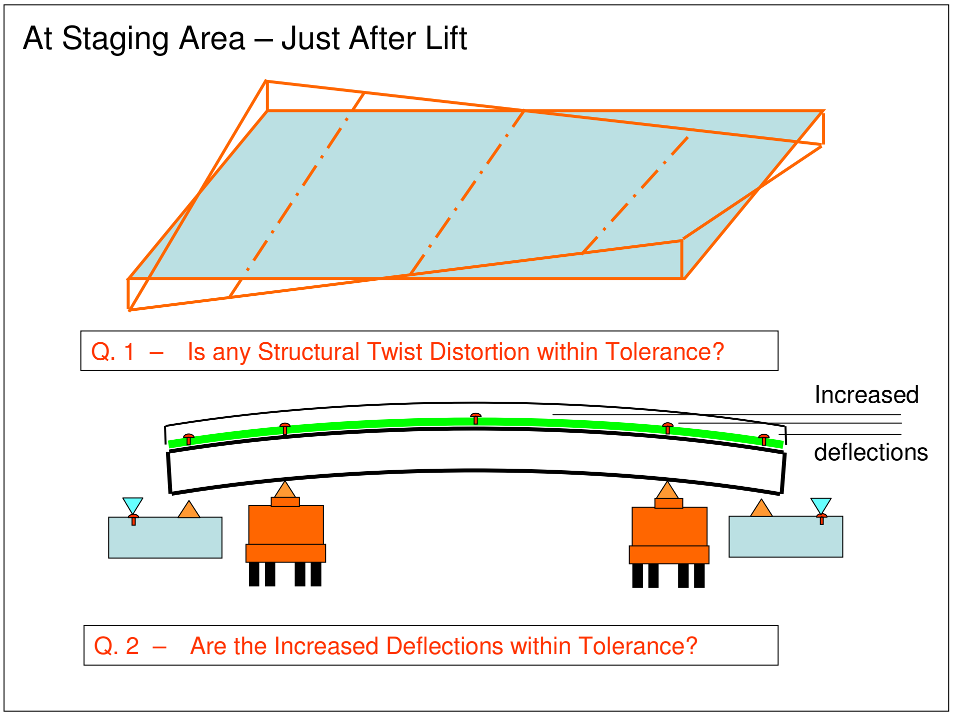


Figure 8.4 Twist and Deflection Questions

The answer to Question 1, the magnitude of the twist (if any) is given by calculating the change in profile shape from the condition just before lift to just after lift. This is illustrated in Figure 8.5. This can be calculated from before and after lift elevations taken either over the center of the SPMT support locations or at the permanent bearing locations. As a guide - a “rule of thumb” - it is recommended that this magnitude be less than the width between the edge beams divided either by 300 (or less than 2”) when observed over the SPMT supports or by 200 when observed over the bearings (or less than 3”) for typical beam-slab decks. The values of 2in and 3in are suggested values. For any particular deck system and size, (length and width) the inspector should verify the provided maximum values provided by the Bridge Specialty Engineer. If the temporary support scheme is as shown in the EOR’s bid plans the Bridge Specialty engineer will have produced values very close to the displacements shown in the plans.

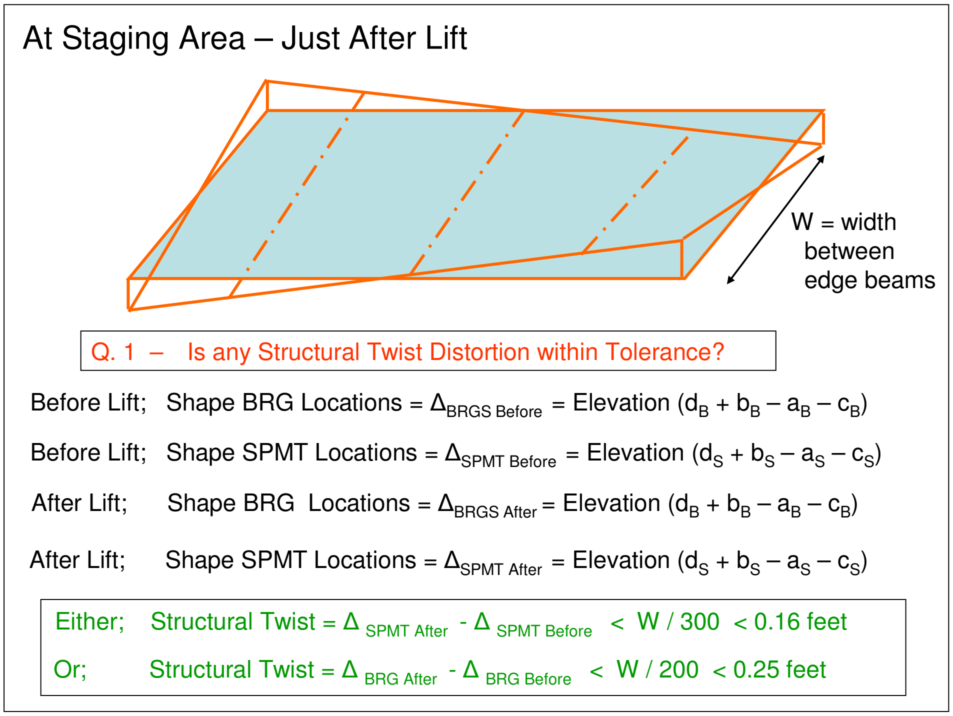


Figure 8.5 Check Structure Twist

Simple techniques may be set up to automatically register any magnitude of twist greater than a maximum allowable amount. For example, one method is to first establish diagonal string-lines from rivets “a” to “c” and from rivet “b” to “d” at a fixed elevation, say about 4”, above the deck slab. Suppose the allowable twist is 3”. Then, instead of only one string-line from “a” to “c”, two are used. At “a”, both are tied “a” at 4in. above the deck. However, at “c” the upper one tied so that it is at 4in +3in = 7in above the deck. The second, lower one is tied at “c” at 4in - 3in = 1in above the deck. At the middle where these cross the string-line from “b” to “d” tied at a constant elevation of 4 in above the deck the upper one will be 1-1/2in above and the lower one will be 1-1/2in below this string-line. During lifting and transportation, any uneven settlement of any one corner relative to the other three will be noticeable by the upper or lower lines contacting the middle one. It goes without saying that electrical contacts attached to the string-lines (or the use of insulated electrical wire, bared at the center) affords the opportunity to automatically signal if twist exceeds a tolerable amount at any time during lifting and moving operations. Variations on this concept would be to use four string-lines from “a” to “c” spaced at intervals higher and lower than the constant elevation to provide an early warning and an absolute, “do not go beyond this limit” warning!

The discussion above has addressed unintended, inadvertent, structural twist. The allowable magnitude can be calculated in advance and simple means can be implemented to detect it and warn operators as and if necessary. This need for monitoring, noted in the FHWA 2007: *Manual on Use of Self-Propelled Modular Transporters to Move Bridges*, Publication No. FHWA-HIF-07-022, will become more important when moving multi-span bridge units.

The magnitude of deflection change from "just before" to "just after" lift condition is determined directly from changes in rivet elevations at the (10) locations of interest. Ideally, the theoretical change should be calculated in advance and compared to observations. As a rough estimate, for a symmetrical condition, relative to the elevation of the mid-point of the span, the ends of the span should deflect downward approximately by the amount given in Figure 8.6 during the change from "just before" to "just after" lifting. The formula is taken from beam theory and should be relatively workable for cases where the distance "a" in Figure 8.6, from the bearings to the centers of the SPMT supports is relatively small - say no more than 15% of the span "L". In cases of doubt, seek guidance from the EOR and Owner.

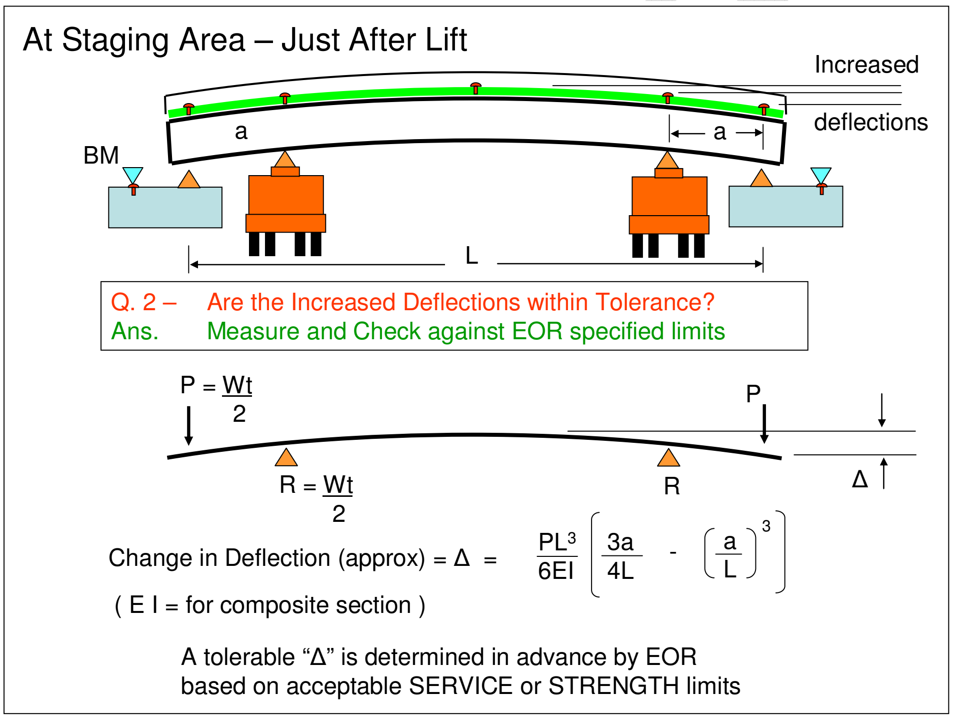


Figure 8.6 Check Deflections

Figure 8.7 shows the survey geometry control process for all key operations from casting the slab to setting the span in place on the final bridge bearings.

The above dialogue addresses the key "Step 2" in this process. However, the principles can be applied to any and all circumstances thereafter, and for moving existing decks. Steps 4 and 5 are the key steps when the span reaches the bridge site and is set down onto the permanent bearings. The same observations and mathematical approach applies.

Should there be a breakdown during transport, then a set of observations can be made as shown in Step 3. Comparison of the elevations and measured deflections relative to previous records from Step 2 during any temporary halt would be information essential for the Engineer to determine if anything detrimental has or might occur and to take appropriate corrective action. This would be done in collaboration with the operators of SPMT system.

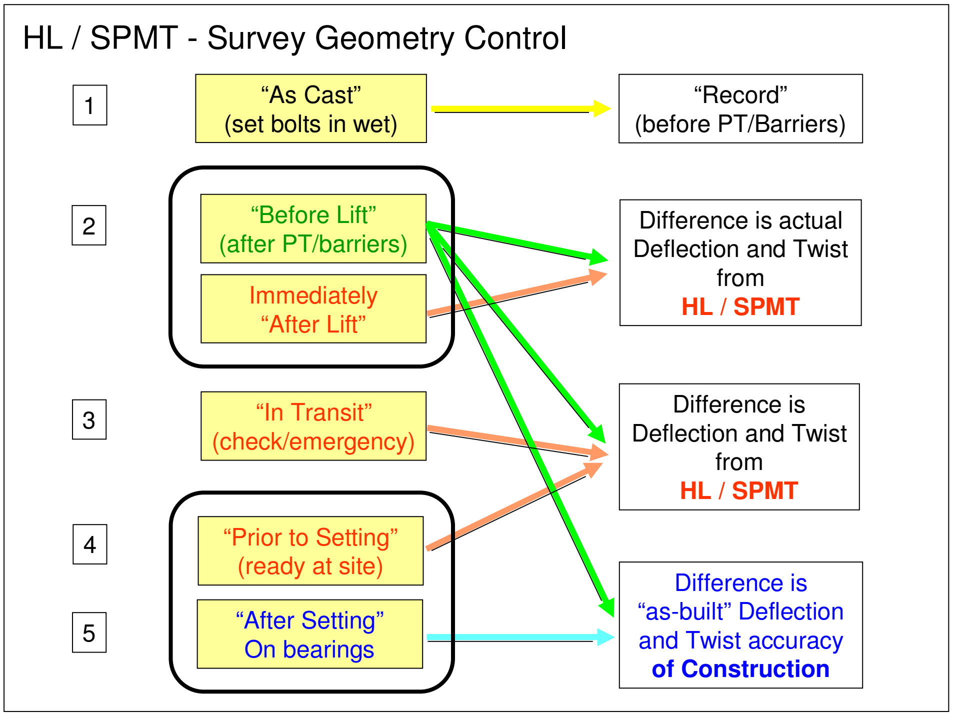


Figure 8.7 Survey Geometry Control Process

Span Stability during Transport - Monitoring

During transportation of the entire span on the SPMT assembly along the travel path (TP), SPMT deck geometry is maintained by their own on-board computerized hydraulic controls. However, since the entire span is to be transported some distance along the travel path, which has its own geometric configuration (profile grade and cross-fall that may vary significantly) there is a need for some overall control upon of the entire span and SPMT assembly to ensure that the longitudinal and transverse tilt remains within stable limits. In turn, this requires a means of on-site monitoring.

For the purpose of on-site monitoring, the change in (a) longitudinal and (b) transverse gradient may be observed using devices set on the deck. One such method would be to use plumb-lines suspended from frames or tripods securely fastened to the deck. The plumb-bobs would be suspended over targets on the deck with the limits if longitudinal and transverse gradient marked. (These limits would be determined by the SPMT Engineer based upon the known performance and expected stability of the entire span and SPMT assembly.) The targets could be inside dash-pots (cans of oil or water) to dampen any wind oscillation. They could also be fitted with sensors (electrical contacts) to detect and warn of the approach of any out of tolerance tilt (change in gradient). Ideally, four plumb-bobs would be used, one at mid-span over each edge beam and one at the mid-point of the width over the bearing diaphragm at each end of the span. Proposals and details for such monitoring would be submitted to the Engineer for approval. Although the Engineer must approve the monitoring details, all the responsibility of the structure and moving system are the responsibility of the SPMT Engineer.

References:

ASBI 2007: *Design Fundamentals and Geometry Control of Segmental Bridges,* American Segmental Bridge Institute, Annual Seminar, Seattle, 2007

ASBI 2005: *Construction Practices Handbook for Segmental Concrete Bridges* American Segmental Bridge Institute, 2005

9.0 Appendix B - List of Heavy Lifters

The list of Heavy Lifters was compiled from an internet search and the directory of Specialized Carrier and Rigging Association (SC&RA) for companies utilizing SPMTs and Heavy Lifters. The list was reduced based on representation of owning enough axle lines to carry 1200 tons. There are over 1200 members in 48 nations. For more recent information and to purchase directory go to the SC&RA website (www.scranet.org). The below list is not being represented as an all inclusive Heavy Lifters list. A sample of offices were contacted and indicated their firm would come to Utah given a large enough project.

B&G Crane Service, LLC
725 Central Avenue
New Orleans, Louisiana 70121-1302
504-733-9400
800-228-5981
504-734-0156 fax
xavierg@bgcrane.com
www.bgcrane.com
X. J. Grilletta, Jr., CEO

Barnhart (Home Office)
1701 Dunn Avenue
Memphis, Tennessee 38106
901-775-3000
800-727-0149
901-775-2992 fax
sales@barnhartcrane.com
www.barnhartcrane.com
Jeff Latture, Sr. Vice President - Sales & Marketing
Will Smith, Heavy Civil Sales
251-654-0541(O)
251-422-0701(Cell)

Bay Crane Service, Inc.
11-02 43rd Avenue
New York City, New York 11101
718-392-0800
718-392-2353 fax
info@baycrane.com
www.baycrane.com
Kenneth Bernardo, President, COO

Bigge Crane and Rigging Co.
10700 Bigge Avenue
PO Box 1657
San Leandro, CA 94577
510-638-8100
510-639-4053 fax
jnelms@bigge.com
www.bigge.com
www.biggeequipment.com
Joe Nelms, V.P. Sales & Marketing

Edwards Moving & Rigging, Inc.
2695 Aiden Road
Cincinnati, Ohio 40065
800-404-6064
502-722-8093 fax
aburns@edwardsmoving.com
www.edwardsmoving.com
Andy Burns, Sales & Project Manager
340 High Street(Branch Office)
Knoxville, Tennessee 37804
800-723-9647
865-448-3538 fax
wesley@edwardsmoving.com
Wesley Knapp, Engineering, Sales & Project Management

Edwards Moving & Rigging, Inc.
21529 E. Illinois Highway 116
Peoria, Illinois 61531
800-478-1631
309-245-2938 fax
kenny@edwardsmoving.com
www.edwardsmoving.com
Kenny Balagna, Sales & Project Management

Erickson's Incorporated
2217 Lake Avenue
North Muskegon, Michigan 49445
231-744-1686
231-744-8996 fax
Steven W. Erickson, President

Fagioli, Inc.
8434 Brookside Road
Pearland, Texas 77581
281-997-3434
713-819-1460 cell
281-997-9848 fax
s.depaoli@fagioli.com
www.fagioli.com
Stefano De Paoli, Engineering and Operational Manager

HWP Rigging

Bullseye Int., LLC
1017 Olive
Suite 1000C
St. Louis, Missouri 63101
314-436-9019
877 MOVE HWP
314-436-7626 fax
robert@hwprigging.com
www.hwprigging.com
Josh Cummings, Sales

Mammoet

Karel Doormanweg 5, PO Box 4(Head Quarters)
PO Box 570
Rotterdam, Netherlands 3100 AN
+31 10 2042424
+31 10 2042442 fax
info@mammoet.com
www.mammoet.com
Roderick van Seimeren, CEO

Mammoet Canada Eastern Ltd.
170 Turnbull Court
Cambridge, Ontario, Canada
519-740-0550
519-740-3531 fax
Tim Sittler, CEO
Glen Aitken, P.Eng., V.P. Engineering & Sales
Bill Halsband, Sales

Mammoet continued.

20525 Farm Road 521(Branch Office)
Houston, Texas 77583
281-369-2200
281-369-2178 fax
sales.america@mammoet.com
Hans van Breukelen, Director of Sales

3236 46th Avenue SE (Branch Office)
Calgary, Alberta, Canada T2B 3K7
403-252-0551
403-258-3846 fax
russ.walters@mammoet.com
Russ Walter, Senior V.P.

1104 70th Avenue(Branch Office)
Edmonton, Alberta, Canada T6P 1P5
780-449-0552
780-417-9623 fax
herman.smit@mammoet.com
Herman Smit, Managing Director

Mamut De Columbia S.A.

Pbx 5422000 Autopista Medellin Calle 80
Km 1 Via a Siberia
Bogota, Columbia
57-1 5422000
57-1 5448399 fax
infomamut@mamut.com.co
Alvaro Madero, CEO

Marino Crane

PO Box 246
Middletown, Connecticut 06457
860-347-0827
800-622-0020
860-347-9870 fax
queries@marinocrane.com
www.marinocrane.com
Joe Zils, General Manager

M.J. Jones Inc. Hauling & Rigging Engineers
PO Box 894
Buffalo, New York 14201
716-447-1876
905-732-9948 fax
mel.jones@mjjones.com
www.mjjones.com
Mel J. Jones, General Manager

Perkins Specialized Transportation Contracting
1800 Riverview Drive
Northfield, Minnesota 55057
651-463-4600
877-PERKINS
651-463-2317 fax
email@heavyhaul.com
www.heavyhaul.com
Jim Meehan, Engineer Manager, Rigging & Moving Manager

Premay Equipment Ltd.
11310 215th Street
Edmonton, Alberta, Canada T5S 2B5
780-447-5555
800-661-9315
780-447-3744 fax
bharris@premayequipment.com
www.premay.com
Brent Harris, President

Rigging International (Home Office)
PO Box 1285
1210 Marina Village Parkway
Alameda, California 94501
510-865-2400
510-865-9450 fax
info@rigginginternational.com
www.rigginginternational.com

Rigging International (Home Office
Victor L. Rollandi, Chairman and Co-Owner
Neil A. Dodds, President and CEO
Carson, California(Branch Office)
310-223-2110
Luiz Crepaldi, Business Development Manager
Missoula, Montana (Branch Office)
406-543-4427
406-543-4505 fax
ptglennon@riggingtinternational.com
Pat Glennon, Vice President, Power Services

Rigging International
Park Center I Office Building
23215 Commerce Park Drive
Suite 201
Beachwood, Ohio 44122
216-595-1550
216-595-1552 fax
riohio@sbc.global.net
www.rigginginternational.com
Steve Bone, Chief Engineer

Sarens s.a.(Corp HQ)
Autoweg 10 B
1861 Wolvertem
Belguim
www.sarens.com
32 52 319 319
32 52 319 329 fax
Steven Sarens, Special Projects – Sales Manager
Steven.sarens@sarens.com

NORSAR LLC (US HQ for SARENS)
4116-34th Avenue NE, #B
Everett, WA 98205
425-259-0213
435-252-5477 fax
www.norsarllc.com
Greg Nordholm, Engineering and Sales
Greg.nordholm@norsarllc.com

Sheedy Drayage Co.
1215 Michigan Street
PO Box 77004
San Francisco, CA 94107
415-648-7171
415-648-1535 fax
info@sheedycrane.com
www.sheedycrane.com
Ken Bouchard, Vice President/Estimating

Southwest Industrial Rigging
2802 W. Palm Lane
Phoenix, AZ 85009-2507
602-278-6281
602-278-5191 fax
info1@swirusa.com
www.swirusa.com
Harry K. Baker, President
Bob Pearson, SPMT Unit Manager

Transport S.R.S. Inc.
1625 Rue Jean Lachaine
Ste-Catherine, Quebec, Canada J5C 1C2
450-638-5566
450-638-1000 fax
d.provost@transportsrs.com
www.transportsrs.com
Daniel Provost, Operation Manager

Turner Bros. Crane & Rigging
1900 Industrial Parkway
Beaumont, Texas 77627
409-729-5600
888-666-6617
409-729-5612 fax
micadk@aol.com
www.turnerbros.com
Mike Adkins, Manager

Turner Industries Group, LLC
PO Box 2750
Baton Rouge, Louisiana 70821
225-922-5050
225-359-6363 fax
mmorain@turner-industries.com
www.turner-industries.com
Mike Morain, Branch Manager

W.J. Casey Trucking & Rigging Co.
25 Meister Avenue
Branchburg, New Jersey 08876-3434
908-809-1200
908-809-1201 fax
www.wjcasey.com
jimmy@wjcasey.com
James V. Biondi, Operations